SCIENCE AND TECHNOLOGY TEXT MINING: NONLINEAR DYNAMICS

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14. ABSTRACT

Database Tomography (DT) is a textual database analysis system consisting of two major components: 1) algorithms for extracting multi-word phrase frequencies and phrase proximities (physical closeness of the multi-word technical phrases) from any type of large textual database, to augment 2) interpretative capabilities of the expert human analyst. DT was used to derive technical intelligence from an Nonlinear Dynamics database extracted from the combined Science Citation Index (SCI)/ Social Science Citation Index (SSCI), hereafter referred to as SCI. Phrase frequency analysis by the technical domain experts provided the pervasive technical themes of the Nonlinear Dynamics database, and the phrase proximity analysis provided the relationships among the pervasive technical themes. Bibliometric analysis of the Nonlinear Dynamics literature supplemented the DT results with author/ journal/ institution publication and citation data.

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ABSTRACT

Database Tomography (DT) is a textual database analysis system consisting of two major components: 1) algorithms for extracting multi-word phrase frequencies and phrase proximities (physical closeness of the multi-word technical phrases) from any type of large textual database, to augment 2) interpretative capabilities of the expert human analyst. DT was used to derive technical intelligence from an Nonlinear Dynamics database extracted from the combined Science Citation Index (SCI)/ Social Science Citation Index (SSCI), hereafter referred to as SCI. Phrase frequency analysis by the technical domain experts provided the pervasive technical themes of the Nonlinear Dynamics database, and the phrase proximity analysis provided the relationships among the pervasive technical themes. Bibliometric analysis of the Nonlinear Dynamics literature supplemented the DT results with author/ journal/ institution publication and citation data.

EXECUTIVE SUMMARY

ES-1. Overview

A text mining analysis of Nonlinear Dynamics was performed. The technical scope included that class of motions in deterministic physical and mathematical systems whose time evolution has a sensitive dependence on initial conditions.

An approximately 100 term query was developed for accessing records from the source SCI database. This query can be used periodically to update the currency of records retrieved.

The bibliometrics sections contained numerical indicators for each bibliometric examined, clustering results for most prolific authors and countries only, and highest frequency elements for each bibliometric. Four technical discipline taxonomies were generated: Keyword non-statistical, Abstract non-statistical, Abstract factor matrix statistical, Abstract multi-link clustering statistical.

ES-2. Bibliometrics

ES-2A. Prolific Authors

There were 6118 papers retrieved, 12136 different authors, and 16370 author listings. Table 2A lists the most prolific authors from 2001, and Table 2B lists the most prolific authors from 1991.

TABLE 2A – MOST PROLIFIC AUTHORS - 2001
(present institution listed)

AUTHOR	INSTITUTION	COUNTRY	# PAPERS
CHEN--GR	CITY UNIV HONG KONG	CHINA	24
LAI--YC	ARIZONA STATE	USA	21
NAYFEH--AH	VPI	USA	16
HU--G	CHINA CTR ADV S&T	CHINA	15
MOSEKILDE--E	TECH UNIV	DENMARK	15
XU--JX	XIAN JIAOTONG UNIV	CHINA	14
AIHARA--K	UNIV TOKYO	JAPAN	13
GASPARD--P	FREE UNIV BRUSSELS	BELGIUM	12
ZHENG--ZG	BEIJING NORMAL UNIV	CHINA	11
ALI--MK	UNIV LETHBRIDGE	CANADA	10
HU--BB	HONG KONG BAPTIST UNIV	CHINA	10
LLIBRE--J	UNIV AUTONOMA BARCELONA	SPAIN	10
GREBOGI--C	UNIV SAO PAULO	BRAZIL	9
KIM--SY	KANGWEON NATIONAL UNIV	SOUTH KOREA	9
KURTHS--J	UNIV POTSDAM	GERMANY	9
KUZNETSOV--SP	RUSSIAN ACADEMY OF SCIENCES	RUSSIA	9
LIU--JM	UCLA	USA	9
LIU--ZR	YUNNAN UNIV	CHINA	9
OTT--E	UNIV MARYLAND	USA	9

Of the nineteen most prolific authors listed in Table 2A, six are from China. In fact, eight are from the Far East, four are from Western Europe, one is from Eastern Europe, five are from North America, and one is from South America. Seventeen are from universities, and two are from research institutes.

To determine the trends in this regional mix of prolific authors, the same query was applied to 1991 only. Table 2B lists the most prolific authors for 1991.

TABLE 2B – MOST PROLIFIC AUTHORS - 1991

AUTHOR	INSTITUTION	COUNTRY	# PAPERS
OTT--E	UNIV MARYLAND	USA	13
GRAHAM--R	UNIV ESSEN GESAMTHSCH	GERMANY	12
PARISI--J	UNIV TUBINGEN	GERMANY	9
YORKE--JA	UNIV MARYLAND	USA	9
VAVRIV--DM	AM GORKII STATE UNIVERSITY	UKRAINE	8
SHEPELYANSKY--DL	NOVOSIBIRSK NUCL PHYS INST	SIBERIA	7
GREBOGI--C	UNIV MARYLAND	USA	6
MANDEL--P	UNIV LIBRE BRUXELLES	BELGIUM	6

SCOTT--SK	UNIV LEEDS	ENGLAND	6
STOOP--R	UNIV ZURICH	SWITZERLAND	6
SWINNEY--HL	UNIV TEXAS	USA	6
TEMAM--R	UNIV PARIS	FRANCE	6
ASHOURABDALLA --M	UCLA	USA	5
BADII--R	LAUSANNE UNIV	SWITZERLAND	5
BUCHNER--J	UCLA	USA	5
CASATI--G	UNIV MILAN	ITALY	5
ELNASCHIE--MS	CORNELL UNIV	USA	5
EPSTEIN--IR	BRANDEIS UNIV	USA	5
ERTL--G	MAX PLANCK GESELL	GERMANY	5

The regional mix of authors has some major differences from the 2001 results. Of the nineteen most prolific authors listed in Table 2B, none are from the Far East, eight are from the USA, nine are from Western Europe, and two are from Eastern Europe. Eighteen are from universities, and one is from a research institute.

Only two names were common to both lists, Ott and Grebogi. However, some researchers can have an off year for a number of reasons, so individual comparisons over two years, especially two widely separated years, may not be overly important. More important are country comparisons, and maybe institutional comparisons to some extent. These entities integrate over many individuals, and their performance would be more reflective of national policy. In this regard, the shift of prolific performers from the NATO countries in 1991 to those of the Far East in 2001 stands out.

Clusters of related authors were generated by two methods: factor matrix and multi-link aggregation. The 253 highest frequency authors were included. Co-author publishing groups were clearly identified, and fine-structure relationships within each group were clearly delineated. Based on name ethnicity alone, intra-country clustering appears to be the dominant form of grouping.

ES-2B. Prolific Journals

There were 1151 different journals represented, with an average of 11.90 papers per journal. The journals containing the most nonlinear dynamics papers (see Table 3A) had more than an order of magnitude more papers than the average.

TABLE 3A – JOURNALS CONTAINING MOST PAPERS - 2001

JOURNAL	# PAPERS
PHYS. REV. E	489
PHYS. REV. LETT.	175
INT. J. BIFURCATION CHAOS	164
PHYS. LETT. A	125

PHYSICA D	113
CHAOS SOLITONS FRACTALS	104
NONLINEAR ANAL.-THEORY METHODS APPL.	100
IEEE TRANS. CIRCUITS SYST. I-FUNDAM. THEOR. APPL.	92
PHYSICA A	85
PHYS. REV. B	84
J. PHYS. A-MATH. GEN.	73
PHYS. REV. A	72
J. FLUID MECH.	56
ACTA PHYS. SIN.	52
PHYS. PLASMAS	51
PHYS. REV. D	51
J. CHEM. PHYS.	48
J. SOUND VIBR.	45
PHYS. SCR.	45
ASTROPHYS. J.	45

The majority of the journals are physics, with the remainder divided between mathematics and electronics. Phys Rev E is the Physical Review journal assigned to chaos, while Phys Rev letters receives important papers for rapid publishing. Many (not all) of the other journals do not focus on nonlinear topics, but include papers in their specialties that also involve nonlinear aspects.

To determine the trends in journals containing the most nonlinear dynamics papers, the results from 1991 are examined. Table 3B contains the top twenty journals.

TABLE 3B – JOURNALS CONTAINING MOST PAPERS - 1991

JOURNAL	# PAPERS
PHYS. REV. A	176
PHYS. LETT. A	98
PHYSICA D	97
PHYS. REV. LETT.	77
J. FLUID MECH.	49
J. CHEM. PHYS.	48
EUROPHYS. LETT.	37
PHYS. REV. B-CONDENS MATTER	37
NONLINEARITY	37
J. PHYS. A-MATH. GEN.	32
GEOPHYS. RES. LETT.	28
J. STAT. PHYS.	28
ASTROPHYS. J.	24
EUR. J. MECH. B-FLUIDS	24
OPT. COMMUN.	23
NONLINEAR ANAL.-THEORY METHODS APPL.	20

PHYS. REV. D	19
LECT. NOTES MATH.	19
INT. J. NON-LINEAR MECH.	18
J. PHYS. CHEM.	17

While the most prolific authors could be expected to change over a decade, for a number of reasons, the most prolific journals should be more stable. Comparison of Tables 3A and 3B shows this to be true. Of the nineteen most prolific journals, eleven are in common. For 2001, two journals were added devoted solely to chaos and closely related topics (CHAOS SOLITONS FRACTALS, INTERNATIONAL JOURNAL OF BIFURCATION AND CHAOS). Perhaps the largest change is the drop of Physical Review A from first in 1991 to twelfth in 2001, and the appearance of Physical Review E as first in 2001. Phys Rev E was split from Phys Rev A during the past decade, and received the Physical Review assignment for papers in chaos.

ES-2C. Prolific Institutions

The most prolific institutions from 2001 are listed in Table 4A, and the most prolific institutions from 1991 are listed in Table 4B.

TABLE 4A – PROLIFIC INSTITUTIONS – 2001

INSTITUTION	COUNTRY	# PAPERS
RUSSIAN ACAD SCI	RUSSIA	165
CHINESE ACAD SCI	CHINA	72
UNIV TOKYO	JAPAN	68
UNIV CALIF SAN DIEGO	USA	67
UNIV MARYLAND	USA	61
UNIV CALIF BERKELEY	USA	53
ARIZONA STATE UNIV	USA	48
UNIV CALIF LOS ANGELES	USA	47
FREE UNIV BRUSSELS	BELGIUM	47
CORNELL UNIV	USA	43
UNIV TEXAS	USA	43
UNIV HOUSTON	USA	41
UNIV ILLINOIS	USA	41
GEORGIA INST TECHNOL	USA	40
PRINCETON UNIV	USA	40
INDIAN INST TECHNOL	INDIA	39
MIT	USA	38
CNRS	FRANCE	37
IST NAZL FIS NUCL	ITALY	36
MAX PLANCK INST PHYS KOMPLEXER SYST	GERMANY	36
TECHNION ISRAEL INST TECHNOL	ISRAEL	36

BEIJING NORMAL UNIV	CHINA	36
MOSCOW MV LOMONOSOV STATE UNIV	RUSSIA	36
NORTHWESTERN UNIV	USA	36
UNIV SAO PAULO	BRAZIL	34
TECH UNIV DENMARK	DENMARK	34
UNIV WASHINGTON	USA	34
UNIV PARIS 06	FRANCE	33
CITY UNIV HONG KONG	CHINA	33
UNIV CAMBRIDGE	ENGLAND	33

Of the thirty most prolific institutions, fourteen are from the USA, seven are from Western Europe, five are from Asia, two are from Eastern Europe, one is from Latin America, and one is from the Middle East. Twenty-five are universities, and the remaining institutions are research institutes. The most prolific institutions for nonlinear dynamics papers correlate well with institutions that have Centers for nonlinear dynamics.

To determine the trends in institutions containing the most nonlinear dynamics papers, the results from 1991 were examined. Table 4B contains the top thirty institutions.

TABLE 4B – PROLIFIC INSTITUTIONS – 1991

INSTITUTION	COUNTRY	# PAPERS
ACAD SCI USSR	USSR	49
UNIV TEXAS	USA	35
MIT	USA	33
UNIV MARYLAND	USA	31
UNIV CAMBRIDGE	ENGLAND	29
USN	USA	29
UNIV CALIF LOS ANGELES	USA	28
CORNELL UNIV	USA	27
UNIV CALIF SAN DIEGO	USA	26
CALTECH	USA	25
ACAD SCI UKSSR	USSR	25
UNIV ILLINOIS	USA	25
UNIV CALIF LOS ALAMOS SCI LAB	USA	24
UNIV ARIZONA	USA	23
UNIV TORONTO	CANADA	22
UNIV CALIF BERKELEY	USA	22
UNIV MINNESOTA	USA	21
UNIV PARIS 11	FRANCE	21
NASA	USA	21
NORTHWESTERN UNIV	USA	20
UNIV LEEDS	ENGLAND	20
GEORGIA INST TECHNOL	USA	19

UNIV ESSEN GESAMTHSCH	GERMANY	19
UNIV HOUSTON	USA	19
UNIV TOKYO	JAPAN	18
MV LOMONOSOV STATE UNIV	USSR	18
UNIV PARIS 06	FRANCE	18
PRINCETON UNIV	USA	17
BROWN UNIV	USA	16
UNIV COLORADO	USA	16

Of the thirty most prolific institutions in 1991, twenty are from the USA, five are from Western Europe, three are from Eastern Europe, one is from Asia, and one is from Canada. The major shift is substitution of Asian institutions for USA institutions.

ES-2D. Prolific Countries

There are 78 different countries listed in the results for 2001. The country bibliometric results are summarized in Table 5A and shown graphically in Figure 1. The dominance of a handful of countries is clearly evident.

TABLE 5A – PROLIFIC COUNTRIES - 2001

COUNTRY	# PAPERS
USA	1797
PEOPLES R CHINA	588
GERMANY	585
JAPAN	470
FRANCE	426
ENGLAND	415
RUSSIA	394
ITALY	338
SPAIN	260
CANADA	242
BRAZIL	173
INDIA	157
NETHERLANDS	141
ISRAEL	127
POLAND	123
AUSTRALIA	118
TAIWAN	110
SOUTH KOREA	109
MEXICO	101
BELGIUM	99
UKRAINE	79
GREECE	74
SWEDEN	71

ARGENTINA	70
DENMARK	60
SCOTLAND	55
SWITZERLAND	53
AUSTRIA	47
HUNGARY	47
EGYPT	35

There appear to be two dominant groupings. The first group is the USA. It has as many papers as the members of the second group, People's Republic of China, Germany, and Japan.

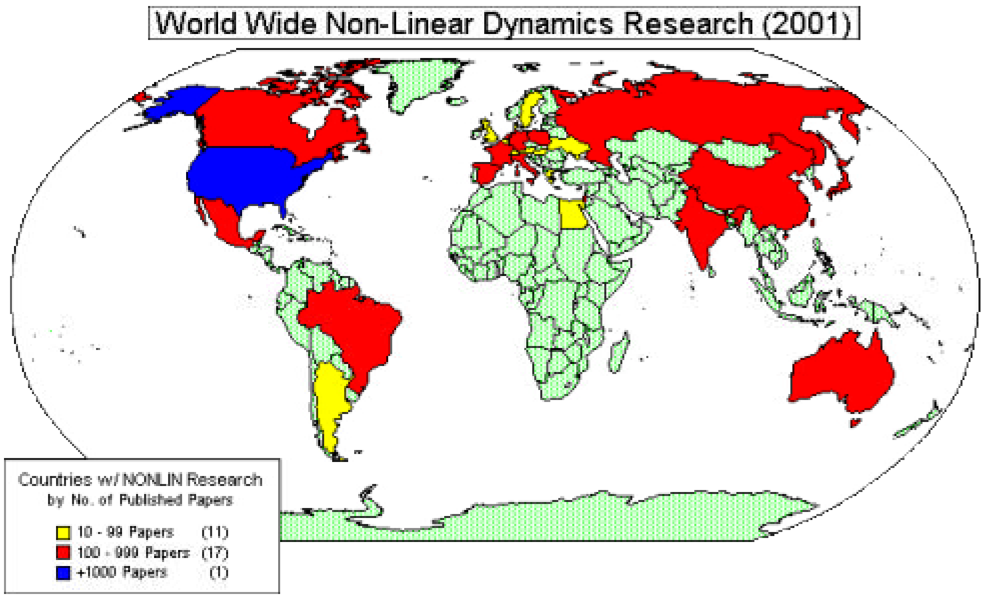


FIGURE 1 – COUNTRIES WITH THE MOST NONLINEAR DYNAMICS PAPERS – 2001

To determine the trends in countries containing the most nonlinear dynamics papers, the results from 1991 were examined. Table 5B summarizes results from the top twenty countries, and Figure 2 displays these results graphically.

TABLE 5B – PROLIFIC COUNTRIES - 1991

COUNTRY	# PAPERS
USA	1031
GERMANY	247
USSR	207
ENGLAND	162
FRANCE	158
JAPAN	154
CANADA	118
ITALY	117
INDIA	65
POLAND	65
PEOPLES R CHINA	63
ISRAEL	52
AUSTRALIA	43
NETHERLANDS	43
SWITZERLAND	40
SPAIN	38
BELGIUM	27
BRAZIL	26
GREECE	25
DENMARK	22
HUNGARY	22
SCOTLAND	22
TAIWAN	22
CZECHOSLOVAKIA	17
SWEDEN	16
AUSTRIA	13
ARGENTINA	11
SOUTH AFRICA	11
MEXICO	10
NORWAY	10

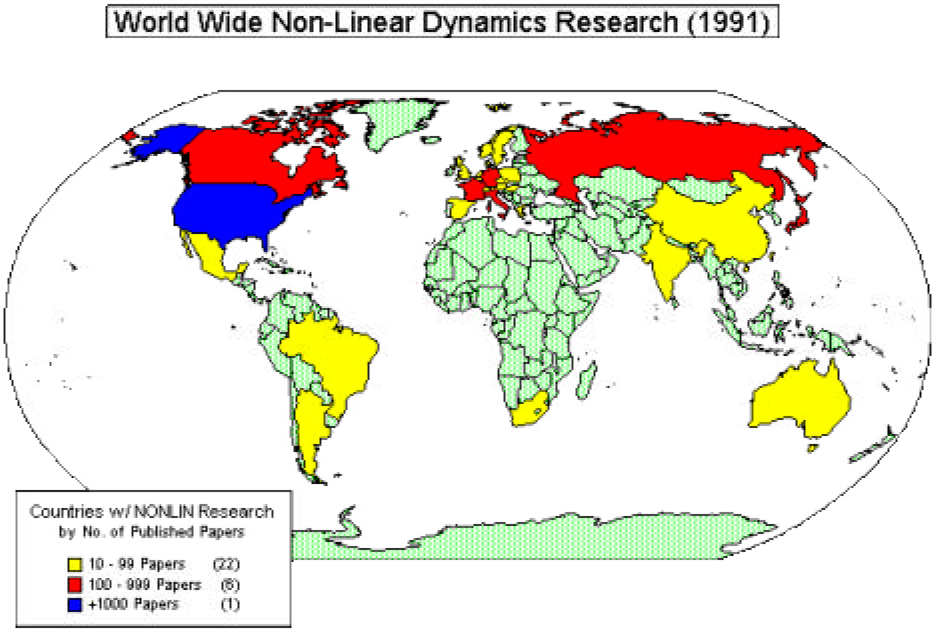


FIGURE 2 – COUNTRIES WITH THE MOST NONLINEAR DYNAMICS PAPERS – 1991

The major shift is the increased ranking of People's Republic of China from 11th in 1991 to 2nd in 2001, and the concomitant increase in numbers of papers from 63 to 584. To place China's increase in Nonlinear Dynamics papers in perspective, it is compared to China's overall increase in SCI papers from 1991 to 2001. In 1991, China had 8174 entries in the SCI, and in 2001, China had 36765 entries in the SCI. Thus, while China's papers in Nonlinear Dynamics in the SCI increased by a factor of ~9.25 from 1991 to 2001, China's overall increase in SCI papers from 1991 to 2001 was a factor of ~4.5. Thus, China's Nonlinear Dynamics papers outpaced its average growth of SCI papers by a factor of ~ 2.

Appendix 4 contains a co-occurrence matrix of the top 15 countries. In terms of absolute numbers of co-authored papers, the USA major partners are Germany, China, France, Canada, and England. Interestingly, the USA is China's dominant major partner, having four times the number of co-authored papers with China (72) as China's next larger partner, Canada (18). Overall, countries in similar geographical regions tend to co-publish substantially, the US being a moderate exception.

ES-2E. Most Cited Authors

The most highly cited authors are listed in Table 6.

TABLE 6 – MOST CITED AUTHORS
(cited by other papers in this database only)

AUTHOR	INSTITUTION	COUNTRY	# CITES
OTT E	UNIV MARYLAND	USA	399
GRASSBERGER P	KFA JULICH GMBH	GERMANY	329
PECORA LM	USN	USA	323
GUCKENHEIMER J	CORNELL	USA	305
NAYFEH AH	VPI	USA	296
KANEKO K	UNIV TOKYO	JAPAN	247
BERRY MV	UNIV BRISTOL	ENGLAND	235
ARNOLD VI	RUSSIAN ACADEMY OF SCIENCE	RUSSIA	230
TAKENS F	UNIV GRONINGEN	NETHERLANDS	212
GASPARD P	FREE UNIV BRUSSELS	BELGIUM	199
GUTZWILLER MC	IBM	USA	194
THEILER J	LOS ALAMOS NATIONAL LAB	USA	194
ABARBANEL HDI	UNIV CAL SAN DIEGO	USA	193
GREBOGI C	UNIV SAO PAULO	BRAZIL	192
LAI YC	ARIZONA STATE	USA	187
ECKMANN JP	UNIV GENEVA	SWITZERLAND	185
LORENZ EN	MIT	USA	174
PIKOVSKY AS	UNIV POTSDAM	GERMANY	172
PRESS WH	HARVARD UNIV	USA	163
CASATI G	UNIV INSUBRIA	ITALY	163

Of the twenty most cited authors, ten are from the USA, seven from Western Europe, one from Russia, one from Japan, and one from Latin America. This is a far different distribution from the most prolific authors of 2001, where eight of nineteen were from the Far East. This distribution of most cited authors more closely resembles the distribution of most prolific authors from 1991, where none were from the Far East. There are a number of potential reasons for this difference between most prolific and cited authors in 2001. The most prolific may not be the highest quality, or many of the most prolific authors could be relatively recent, and insufficient time has elapsed for their citations to accumulate. In another three or four years, when the papers from present-day authors have accumulated sufficient citations, firmer conclusions about quality can be drawn.

The lists of nineteen most prolific authors from 2001 and twenty most highly cited authors only had five names in common (OTT, NAYFEH, GASPARD, GREBOGI, LAI). This phenomenon of minimal intersection has been observed in all other text mining studies performed by the first author.

Fifteen of the authors' institutions are universities, four are government-sponsored research laboratories, and one is a private company.

The citation data for authors and journals represents citations generated only by the specific records extracted from the SCI database for this study. It does not represent all the citations received by the references in those records; these references in the database records could have been cited additionally by papers in other technical disciplines.

ES-2F. Most Cited Papers

The most highly cited documents are listed in Table 7.

TABLE 7 – MOST CITED DOCUMENTS
(total citations listed in SCI)

AUTHOR NAME	YEAR	JOURNAL	VOLUME/ PAGE	SCI CITES
PECORA LM	1990	PHYS REV LETT	V64,P821	938
(SYNCHRONIZATION IN CHAOTIC SYSTEMS)				
GUCKENHEIMER J	1983	NONLINEAR OSCILLATIONS		
(MATHEMATICAL STUDIES OF BIFURCATIONS)				
OTT E	1990	PHYS REV LETT	V64,P1196	1274
(CONTROLLING CHAOS)				
LORENZ EN	1963	J ATMOS SCI	V20,P130	2971
(DETERMINISTIC NONPERIODIC FLOW)				
CROSS MC	1993	REV MOD PHYS	V65,P851	1500
(PATTERN-FORMATION OUTSIDE OF EQUILIBRIUM)				
WOLF A	1985	PHYSICA D	V16,P285	1566
(DETERMINING LYAPUNOV EXPONENTS FROM A TIME-SERIES; INTRODUCED CHAOS)				
TAKENS F	1981	LECT NOTES MATH	V898,P366	
(MATHEMATICAL PAPER ON ANALYSIS OF CHAOTIC TIME SERIES)				
OTT E	1993	CHAOS DYNAMICAL SYST		
(CHAOS CONTROL THEORY)				
GRASSBERGER P	1983	PHYSICA D	V9,P189	1567
(MEASURING THE STRANGENESS (FRACTAL GEOMETRY) OF STRANGE ATTRACTORS)				
GUTZWILLER MC	1990	CHAOS CLASSICAL QUAN		
(QUANTUM IDEAS ON CHAOS)				
ROSENBLUM	1996	PHYS REV LETT	V76,P180	241

MG		4	
*(**PHASE SYNCHRONIZATION OF CHAOTIC OSCILLATORS)***			
GRASSBERGER P	1983 PHYS REV LETT	V50,P345	1369
*(**CHARACTERIZATION OF STRANGE ATTRACTORS IN AN OSCILLATOR'S PHASE SPACE)***			
ECKMANN JP	1985 REV MOD PHYS	V57,P617	1557
*(**ERGODIC-THEORY OF CHAOS AND STRANGE ATTRACTORS)***			
THEILER J	1992 PHYSICA D	V58,P77	568
(SURROGATE DATA TESTING FOR NONLINEARITY IN TIME-SERIES)			
NAYFEH AH	1979 NONLINEAR OSCILLATIONS		
(TEXTBOOK ON NONLINEAR MECHANICS)			
FUJISAKA H	1983 PROG THEOR PHYS	V69,P32	294
*(**STABILITY THEORY OF SYNCHRONOUS MOTION IN COUPLED-OSCILLATOR SYSTEM)***			
WIGGINS S	1990 INTRO APPL NONLINEAR		
(APPLIED NONLINEAR DYNAMICAL SYSTEMS AND CHAOS)			
RULKOV NF	1995 PHYS REV E	V51,P980	213
*(**SYNCHRONIZATION OF CHAOS IN DIRECTIONALLY COUPLED CHAOTIC SYSTEMS)***			
PYRAGAS K	1992 PHYS LETT A	V170,P421	512
*(**CONTINUOUS CONTROL OF CHAOS BY SELF-CONTROLLING FEEDBACK)***			
LICHTENBERG AJ	1992 REGULAR CHAOTIC DYNA		
(CHAOTIC MOTION IN NONLINEAR DYNAMICAL SYSTEMS)			

The theme of each paper is shown in italics on the line after the paper listing. The order of paper listings is by number of citations by other papers in the extracted database analyzed. The total number of citations from the SCI paper listing, a more accurate measure of total impact, is shown in the last column on the right.

Physical Review Letters contains the most papers by far, four out of the twenty listed. Most of the journals are fundamental science journals, and most of the topics have a fundamental science theme. The majority of the papers are from the 1990s, with seven from the 1980s, one from the 1970s, and one extremely highly cited paper being from 1963. This reflects a dynamic research field, with seminal works being performed in the recent past.

Eight of the papers address issues related to chaos, with the dominant themes being conditions for determining chaos, and properties of strange attractors. Four of the papers address issues related to synchronization, with the focus on coupled chaotic oscillators.. Three of the papers address issues related to control, emphasizing self-controlling feedback. One paper addresses stability-related issues, focusing on

bifurcations, and one paper focuses on quantum chaos. There are three nonlinear dynamics books in the top twenty cited documents.

Thus, the major intellectual emphasis of cutting edge Nonlinear Dynamics research, as evidenced by the most cited papers, is well aligned with the intellectual heritage and performance emphasis, as will be evidenced by the clustering approaches.

ES-2G. Most Cited Journals

Table 8 lists the most highly cited journals.

TABLE 8 – MOST CITED JOURNALS
(cited by other papers in this database only)

JOURNAL	TIMES CITED
PHYS REV LETT	10786
PHYS REV E	5310
PHYS REV A	3603
PHYSICA D	3579
PHYS LETT A	2308
J CHEM PHYS	2138
J FLUID MECH	2002
PHYS REV B	1969
NATURE	1911
ASTROPHYS J	1367
INT J BIFURCAT CHAOS	1279
SCIENCE	1256
PHYS REV D	1215
J PHYS A-MATH GEN	1073
PHYS FLUIDS	907
J ATMOS SCI	871
REV MOD PHYS	864
PHYS REP	813
J STAT PHYS	790
CHAOS	777

The first two groups of cited journals clearly stand out. PHYS REV LETT received almost as many cites as the three journals in the next group (PHYS REV E, PHYS REV A, PHYSICA D), or even the five journals in the following group (PHYS LETT A, J CHEM PHYS, J FLUID MECH, PHYS REV B, NATURE). PHYS REV LETT emphasizes rapid publication of 'hot' topics, and would therefore tend to establish primacy in an emerging field. Since one aspect of citations is identifying the original literature of a new topic, a credible journal with these characteristics would tend to receive large numbers of citations.

Unlike the relatively disjoint relationship between most prolific authors in 2001 and most cited authors, the relationship between most prolific journals in 2001 and most cited journals was much closer. Nine of the ten most highly cited journals were also on the list of twenty most prolific journals in 2001. The more applied journals on the most prolific list for 2001 are replaced by the more fundamental journals on the most cited list.

ES-3. Technical Discipline Taxonomies

ES-3A. Keywords Manual Taxonomy

All the Keywords from the extracted SCI records, and their associated frequencies of occurrence (with a threshold frequency of nine), were tabulated, and then grouped into categories by visual inspection. The phrases were of two types: applications-related and phenomena or tech base-related. While the application sub-categories were relatively independent, there was substantial overlap between some of the tech base categories. The detailed taxonomy results are presented in Appendix 5. Within each sub-category, thrust areas are presented in approximate frequency appearance order. These results are displayed in Table 9, and summarized now.

TABLE 9 – KEYWORD TAXONOMY

SUB-CATEGORIES	SUB-CAT FREQ SUMS	CATEGORIES	CAT FREQ SUMS
FLUID FLOW	845	APPLICATIONS	845
OPTICS	273	APPLICATIONS	1118
BRAIN	277	APPLICATIONS	1395
ENVIRONMENT	131	APPLICATIONS	1526
COSMOLOGY	147	APPLICATIONS	1673
MATERIALS	88	APPLICATIONS	1761
CHEMISTRY	82	APPLICATIONS	1843
PLASMA	76	APPLICATIONS	1919
SPATIAL BOUNDARY	56	BOUNDARIES	56
INITIALIZATION	46	BOUNDARIES	102
SIGNALS	667	COMMUNICATION	667
CIRCUITS	102	COMMUNICATION	769
CONTROL	216	CONTROL	216
SYNCHRONIZATION	397	COUPLING	397
RESONANCE	149	COUPLING	546
OSCILLATIONS	693	CYCLING	693
PERIODICITY	250	CYCLING	943
WAVES	234	CYCLING	1177
EXPERIMENT	193	EXPERIMENT	193
GEOMETRY	146	GEOMETRY	146
MODEL AND SIM	1012	MODEL AND SIM	1012

EVOLUTION	1870	MOTION	1870
CHAOS	1056	MOTION	2926
QUANTUM	520	SCALING	520
DIMENSIONALITY	205	SCALING	725
LOCALIZATION	88	SCALING	813
SCALING	38	SCALING	851
STABILITY	1378	STABILITY	1378
MAPS	115	STABILITY	1493
NONLINEAR	222	STRUCTURES	222
STATES	298	STRUCTURES	520
THEORY	215	THEORY	215
ENTROPY	284	THERMODYNAMICS	284
NOISE	144	THERMODYNAMICS	428
STATISTICS	142	THERMODYNAMICS	570
DISSIPATION	78	THERMODYNAMICS	648
THERMODYNAMICS	59	THERMODYNAMICS	707
CONSERVATION	42	THERMODYNAMICS	749

There are eight distinct applications categories, with four levels of stratification based on phrase frequency summations. Fluid Flow is the dominant stratification level, with the main emphasis being turbulence, convective transport, and diffusion. The second stratification level consists of Optics and Brain. The Optics emphases are lasers and associated nonlinear phenomena, while the Brain emphases are neural networks and analyses of broader neural system signals. The third stratification level consists of Environment and Cosmology. The Environment emphases are earthquakes and storms, while the Cosmology emphases center around evolution of the universe. The fourth stratification level consists of Materials, Chemistry, and Plasma (mostly fusion physics based). The Materials emphasis are split between solid mechanics/ structures issues and electronic properties/ applications issues.

There are fourteen tech base categories, also with four main stratification levels based on phrase frequency summations. The dominant level is Motion, consisting of the sub-categories Evolution and Chaos. Evolution emphases are attractors and nonlinear dynamics. The second level consists of Stability, comprised of the sub-categories Stability and Maps. Stability emphases are bifurcations and the transitions to instability, while Maps emphasizes Poincare’s surface intersections. The third level comprises Cycling and Modeling and Simulation, with Cycling further categorized into Oscillations, Periodicity, and Waves. Under Oscillations, nonlinear, chaotic, and coupled oscillators are emphasized, as well as limit cycles; under Periodicity, the focus is periodic orbits; and under Waves, the emphasis is traveling and solitary waves.

The fourth stratification level consists of Communication, Scaling, Thermodynamics, and Coupling. Communication comprises Signals and Circuits; Scaling comprises Quantum, Dimensionality, Localization, and Scaling; Thermodynamics comprises Entropy, Noise, Statistics, Dissipation, Thermodynamics, and Conservation; and Coupling comprises Synchronization and Resonance. .Under Signals, time series

analysis and the associated intermittency are emphasized; under Quantum, small particle motions and interactions are emphasized; under Dimensionality, different measures of fractal dimensions of strange attractors are emphasized; under Entropy, patterns and pattern formation are emphasized; under Noise, brownian motion is emphasized; under Dissipation, hysteresis and friction are emphasized; and under Resonance, stochastic resonance is emphasized.

ES-3B. Abstracts Manual Taxonomy

A taxonomy of nonlinear dynamics applications and phenomena was developed through visual inspection of the TextDicer Abstract phrase frequencies. The developed taxonomy was subsequently used to approximate global levels of emphasis (GLE). This type of analysis would help identify adequately and inadequately supported system and subsystem tech base areas. It could also differentiate the developed and developing technology components of a particular system.

Table 10 contains the manual Abstract taxonomy.

TABLE 10 – MANUAL ABSTRACT TAXONOMY

SUB-CATEGORY	NON-MARG UTIL SUB-CAT FREQ SUMS	CATEGORY	NON-MARG UTIL CAT FREQ SUMS
FLUID FLOW	1025	APPLICATIONS	
CHEMISTRY	359	APPLICATIONS	
COSMOLOGY	353	APPLICATIONS	
BRAIN	606	APPLICATIONS	
MATERIALS	217	APPLICATIONS	
ENVIRONMENT	404	APPLICATIONS	
LASER	348	APPLICATIONS	
MEDICAL	204	APPLICATIONS	
GEOLOGY	274	APPLICATIONS	
BIOLOGY	246	APPLICATIONS	
SOLID STATE	264	APPLICATIONS	
OPTICAL	506	APPLICATIONS	
OCEAN	167	APPLICATIONS	
PLASMA	174	APPLICATIONS	
POPULATION	33	APPLICATIONS	5180
TIME BOUNDARY	300	BOUNDARIES	
SPATIAL BOUNDARY	314	BOUNDARIES	614
SIGNALS	1081	COMMUNICATION	
CIRCUITS	220	COMMUNICATION	
COMMUNICATION	136	COMMUNICATION	

CODE	61	COMMUNICATION	1530
CONTROL	1361	CONTROL	1361
SYNCHRONICITY	591	COUPLING	
COUPLING	319	COUPLING	
RESONANCE	465	COUPLING	1375
OSCILLATIONS	2106	CYCLING	
PERIODICITY	919	CYCLING	
WAVE	440	CYCLING	3465
EXPERIMENTS	1073	EXPERIMENT	1073
GEOMETRY	580	GEOMETRY	580
MODEL AND SIM	1931	MODEL AND SIM	1931
EVOLUTION	1218	MOTION	
CHAOS	554	MOTION	
ATTRACTORS	799	MOTION	2571
QUANTUM	1210	SCALING	
DIMENSIONALITY	491	SCALING	
SCALING	739	SCALING	
LOCALIZATION	122	SCALING	2562
STABILITY	3199	STABILITY	
MAPS	655	STABILITY	3854
NONLINEAR	678	STRUCTURES	
STATES	422	STRUCTURES	1100
THEORY	285	THEORY	285
NOISE	416	THERMODYNAMICS	
STATISTICS	154	THERMODYNAMICS	
ENTROPY	256	THERMODYNAMICS	
DISSIPATION	303	THERMODYNAMICS	
THERMODYNAMICS	118	THERMODYNAMICS	1247

Relative to the Keyword taxonomy, the Abstract taxonomies have two additional categories: Biology and Medical. While biological and medical terms can be found in the list of Keywords, they occur with a frequency lower than that used for cutoff. The reasons for this are unclear. In the Abstract phrase taxonomies, Biological and Medical are not the lowest frequency applications, and if the Keywords correlated with the Abstract phrases, one would expect Biology and Medicine to appear as Keyword taxonomy categories. It could be that: 1) the biomedical community uses a greater fraction of nonlinear dynamics phenomenological terms as Keywords than other application communities; 2) there is less agreement on medical terminology relative to other communities, and a greater variety of low frequency terms are used; or 3), a broader variety of medical sub-areas are being investigated with nonlinear dynamics than some of the other applications areas.

In addition, some new categories were generated for the Abstract taxonomies by fissioning categories in the Keywords taxonomy. For example, Optics in the Keywords taxonomy was split into Optics and Lasers for the Abstracts taxonomies, due to the

substantially greater amount of Abstract phrase detail, but it is fundamentally the same category.

Now, the emphasis areas of the Abstract phrase categories will be summarized.

Applications can be stratified into four main levels, based on summation of phrase frequencies as figure-of-merit. The dominant level consists of Fluid Flow (1025) and Optics (854), the latter including both Optical (506) and Laser (348). Fluid Flow emphasizes turbulence, vorticity, and convection; Optics emphasizes lasers and beams (generically electromagnetic beams, but usually laser or light beams).

The second level consists of Brain (606). Brain emphasizes neuron firings, EEG, epilepsy, and cortex.

The third level consists of Chemistry (359), Cosmology (353), Environment (404), and Material (481), the latter including both Materials (217) and Solid State (264). Chemistry emphasizes reaction and diffusion rates, combustion, catalysis, and Belousov-Zhabotinsky reaction; Cosmology emphasizes galaxies, black holes, and planets; Environment emphasizes atmosphere, weather (wind, climate, storms, rainfall), and ecology; Material emphasizes polymers, viscoelasticity, crystals, semiconductors, diodes, and tunneling.

The fourth major level consists of Medical (204), Geology (274), and Biology (246), Medical emphasizes cardiovascular problems (cardiovascular, blood pressure, fibrillation, heart rate, ventricular, pacemaker), and infectious disease (infection, virus).

Phenomena can be stratified into three main levels, based on summation of phrase frequencies as figure-of-merit. The dominant level consists of Stability (3854) and Cycling (3465). The Stability category can be divided into a Stability sub-category (3199) and a Maps sub-category (655). The Cycling category can be divided into an Oscillations sub-category (2106), a Periodicity sub-category (919), and a Wave sub-category (440).

Within the Stability category, the Stability sub-category emphasizes Hopf, pitchfork, period-doubling, global, saddle-node, homoclinic, local, transcritical, blowout, primary, and subcritical bifurcations, and bifurcation points/ diagrams/ curves/ structure/ control/ set/ buckling/ mechanism, stability and instability [LINEAR AND NONLINEAR STABILITY ANALYSIS, STABLE AND UNSTABLE PERIODIC ORBITS, ASYMPTOTIC STABILITY, ONSET OF INSTABILITY, UNSTABLE FIXED POINT(S), STABLE LIMIT CYCLE(S), UNSTABLE PERIODIC SOLUTIONS, CONDITIONS OF STABILITY, LINEAR STABILITY THEORY], Lyapunov criteria, and critical and equilibrium points; the Maps sub-category emphasizes Poincare, logistic, Henon, return, standard, circle, invertable and non-invertable, Ikeda, unimodal, area-preserving, symplectic, and quadratic maps, center, invariant, stable and unstable, slow, compact, homoclinic, inertial, riemannian, Stiefel, and symplectic manifolds, and normal forms.

Within the Cycling category, the Oscillations sub-category emphasizes oscillators, vibrators, and limit cycles; the Periodicity sub-category emphasizes homoclinic, circular, chaotic, periodic, and quasi-periodic orbits, period doubling, and periodic points; the Wave sub-category emphasizes acoustic, gravity, nonlinear, solitary, spiral, standing, traveling, and water waves, wave equations, fronts, and packets, and wave forms and numbers.

The second level consists of Motion (2571), Scaling (2562), and Modeling and Simulation (1931). The Motion category can be divided into an Evolution sub-category (1218), a Chaos sub-category (554), and an Attractors sub-category (799). The Scaling category can be divided into a Quantum sub-category (1210), a Dimensionality sub-category (491), a Scaling sub-category (739), and a Localization sub-category (122).

Within the Motion category, the Evolution sub-category emphasizes dynamical systems, nonlinear dynamics, chaotic dynamics, time and nonlinear evolution, system and population dynamics; the Chaos sub-category emphasizes chaotic systems, motions, orbits, regimes, states, scattering, and trajectories, onset of chaos, transition to chaos, deterministic chaos, routes to chaos, and spatiotemporal chaos; the Attractors sub-category emphasizes chaotic, global, strange, coexisting, fixed point, periodic, great, hyperchaotic, multiple, random, stable, compact, and dynamical attractors, basins, attracting sets, attractor networks and dimensions.

Within the Scaling category, the Quantum sub-category emphasizes dynamics of small particles [ELECTRONS, IONS, ATOMS, MOLECULES, NUCLEI, PROTONS], lattices, quantum chaos/ dots/ dynamics/ interference/ mechanics/ states/ systems, the Schrodinger equations, and billiard models; the Dimensionality sub-category emphasizes correlation, fractal, embedding, Hausdorff, generalized, range, high and low, and finite dimensions, and degrees of freedom; the Scaling sub-category emphasizes fractals, time and length scales, and self-similarity; the Localization sub-category emphasizes dynamical, nonlinear, spatial, weak, Anderson, and electron localization, intrinsic localized modes, locally transversal linearization, localization length, localized states, and local linearization.

The Modeling and Simulation category emphasizes nonlinear, ordinary and partial differential, stochastic differential, delay differential, functional differential, difference, Navier-Stokes, reaction-diffusion, Fokker-Planck, constitutive, algebraic, Klein-Gordon, KDV, Burger, Euler, Boltzmann, Duffing, Lorenz, Mathieu, and Kuramoto-Sivashinsky equations, equations of motion, control, genetic, numerical, learning, backpropagation, decoding, and Grassberger-Procaccia algorithms, simulated annealing, numerical, computer, dynamical, model, nonlinear, direct, stochastic, monte carlo, and molecular dynamics simulations. and neural network, finite element, nonlinear dynamical, mathematical, numerical, linear and nonlinear, oscillator, chaotic, neuron, circuit, fuzzy, stochastic, mechanical, food chain, and general circulation models.

The third level consists of Communication (1530), Control (1361), Coupling (1375), Thermodynamics (1247), Structures (1100), and Experiment (1073). The

Communication category can be divided into a Signals sub-category (1081), a Circuits sub-category (220), a Communications sub-category (136), and a Code sub-category (61). The Coupling category can be divided into a Synchronicity sub-category (591), a Coupling sub-category (319), and a Resonance sub-category (465). The Thermodynamics category can be divided into a Noise sub-category (416), a Statistics sub-category (154), an Entropy sub-category (256), a Dissipation sub-category (303), and a Thermodynamics sub-category (118). The Structures category can be divided into a Nonlinear sub-category (678) and a States sub-category (422).

Within the Communication category, the Signals sub-category emphasizes chaotic, output and input, driving, control, beat, coupled, digital, error, external, microwave, nonlinear, and reference signals, time series, harmonic, anharmonic, and sub-harmonic, information and signal processing, and intermittency; the Circuits sub-category emphasizes electronic, chaotic, equivalent, nonlinear, shunt, and Pikovsky circuits; Josephson Junctions, and switches; the Communications sub-category emphasizes secure, chaotic, digital, and spread spectrum communications, and communication systems, communication channel the Code sub-category emphasizes coding and decoding, encryption, and security.

The Control category emphasizes feedback, delayed feedback, optimal, adaptive, nonlinear, chaos, robust, motion, tracking, active, mode, sliding mode, bifurcation, variable structure, and hybrid control, feedback, feed-forward, back-propagation, control system/ law/ strategy/ algorithm/ design/ theory.

Within the Coupling category, the Synchronicity sub-category emphasizes phase, chaos, generalized, global, asymptotic, lag, projective, and adaptive synchronization, phase, frequency, mode, and injection locking, discrete breathers, and synchronization error; the Coupling sub-category emphasizes coupled chaotic, coupled systems, coupling strength, strong coupling, weak coupling, and unidirectional coupling; and the Resonance sub-category emphasizes stochastic, internal, parametric, coherence, nonlinear, strong, size, primary, magnetic, cyclotron resonance, and resonance frequencies/ modes/ states. .

Within the Thermodynamics category, the Noise sub-category emphasizes white, gaussian, external, additive, colored, measurement, random, dynamical, channel, correlated, stochastic, and thermal noise, and noise reduction/ intensity/ correlation/ amplitude/ sources, and Brownian Motion; the Statistics sub-category emphasizes Bose-Einstein, Bayesian, Ergodicity, Markov Chain, spectral, eigenvector, and Poisson statistics, and statistical properties/ mechanics/ ensembles/ distributions/ moments/ physics/ theory; the Dissipation sub-category emphasizes energy, tidal, numerical, artificial, and viscous dissipation, dissipative systems/ solitons/ structures/ dynamics/ models/ chaos/ maps, hysteresis; the Entropy sub-category emphasizes Kolmogorov, topological, approximate, information, Neumann, Shannon, linear, maximum, and Tsallis entropy, entropy production/ balance/ correlation/ fluctuations/ flux/ perturbations, spatial, wave, and spatiotemporal patterns, and pattern formation and recognition; the

Thermodynamics sub-category emphasizes thermodynamic limits and equilibrium, adiabatic approximation, and nonadiabatic systems and dust .

Within the Structures category, the Nonlinear sub-category emphasizes nonlinear systems/ interactions/ effects/ equations/ response/ terms/ regime/ phenomena/ function/ processes/ elastic/ prediction/ optimization/ stochastic/ viscoelastic/ dependence/ state/ boundary/ crystal/ structure; the States sub-category emphasizes ground, coherent, equilibrium, bound, stationary, excited, transition, basic, system, quiescent, rest and turbulent states, and state variables/ estimation/ vectors. .

The Experiment category emphasizes experimental results/ data/ observations/ measurements/ evidence/ conditions/ models/ verification/ techniques/ apparatus/ device/ dynamics, numerical, laboratory, computer, simulation, independent, and physical experiments, electric, magnetic, and electromagnetic fields, MEMS, microscopy, and spectroscopy,

The remaining categories are small, and will not be discussed further.

ES-3C. Abstract Factor Matrix Taxonomy

The highest frequency high technical content phrases, with record frequencies not below seven, were identified (640 phrases). Very similar phrases were consolidated (e.g., singulars/ plurals, full spellings/ acronyms, strong synonyms), as shown by the process in Appendix 7. A correlation matrix of the 253 resultant consolidated phrases was generated, and a factor analysis was performed using the WINSTAT statistical package. The eigenvalue floor was set equal to unity, and a factor matrix consisting of 20 factors resulted. A description of each factor, and their aggregation into a taxonomy, follows. The capitalized phrases in parentheses represent typical high factor loading phrases for the factor described. Typically, the first few phrases presented dominate the themes. The complete factor matrix is presented in Appendix 8.

Factor 1 (BIFURCATIONS, STABILITY, POINCARE MAPS, PERIODIC MOTIONS, PERIODIC SOLUTIONS, PHASE PLANE, LIMIT CYCLES, PHASE PORTRAITS, FIXED POINTS, PERIOD DOUBLING, EQUILIBRIUM POINTS, also including LYAPUNOV EXPONENTS, NORMAL FORMS, FLOQUET THEORY) – focuses on stability of periodic systems, emphasizing onset and prediction of instabilities. Examines routes to chaos through bifurcation and associated period doubling, using reduced and normal forms of the Poincare map, as well as phase plane trajectories to plot the motions.

Factor 2 (CLASSICAL SYSTEM, CLASSICAL LIMIT, QUANTUM SYSTEMS, QUANTUM DYNAMICS, TRACE FORMULA, QUANTUM MECHANICS, TIME EVOLUTION, CLASSICAL DYNAMICS, DYNAMICAL EVOLUTION, BROWNIAN MOTION, also including QUANTUM-CLASSICAL CORRESPONDENCE, DECOHERENCE, COHERENT STATES) – focuses on correspondence between quantum dynamical systems and classical systems, especially focusing on the classical

limit behavior of quantum systems, as well as the trace formula's semiclassical representation for a quantum system's density of states in terms of the periodic orbits of the underlying classical dynamics.

Factor 3 (RANDOM MATRIX THEORY, ENERGY LEVELS, SPECTRAL STATISTICS, STATISTICAL PROPERTIES, EIGENFUNCTIONS, QUANTUM-CLASSICAL CORRESPONDENCE, ERGODICITY, WAVE FUNCTIONS, also including CHAOS, PERIODIC ORBITS, QUANTUM DOTS) – focuses on potential links between the statistical distribution of the energy levels of classically chaotic systems and the eigenvalue correlations of random matrix theory, or between the quantum properties of individual deterministically chaotic systems and of ensembles of randomly disordered systems.

Factor 4 (BASINS, ATTRACTORS, INVARIANT SUBSPACE, COUPLED CHAOTIC SYSTEMS, INTERMITTENCY, SYMMETRY BREAKING, MANIFOLDS, also including FRACTALS, SCALING, INVARIANT SETS, GLOBAL DYNAMICS, BIFURCATIONS, PHASE PLANE) – focuses on formation of riddled basins (every point in a chaotic attractor's basin has pieces of another attractor's basin arbitrarily nearby) and off-on intermittency by the loss of transverse stability of an invariant subspace containing a chaotic attractor; examines the effect of perturbation-induced symmetry-breaking on blowout-bifurcations (accompanying Lyapunov exponent sign reversal) that create riddled basins.

Factor 5 (SYNCHRONIZED, FREQUENCY DETUNING, FEEDBACK, COUPLING, LASERS, NOISE, GENERALIZED SYNCHRONIZATION, PHASE LOCKING, COHERENCE RESONANCE, DRIVE SYSTEM, CHUA'S C'RCUIT, LORENZ SYSTEM, INFORMATION SIGNAL, CHAOTIC DYNAMICAL SYSTEMS, also including WEAKLY NONLINEAR ANALYSIS, PATTERN FORMATION, CHAOS, NEURAL NETWORKS, NEURONS, OSCILLATORS) – focuses on synchronization of chaotic dynamical systems, especially optically coupled diode lasers with optical feedback, and examines synchronization robustness with respect to frequency detuning.

Factor 6 (LYAPUNOV EXPONENTS, POWER SPECTRUM, CORRELATION DIMENSIONS, TIME SERIES, KOLMOGOROV ENTROPY, FRACTALS, HEART RATE, SPECTRAL ANALYSIS, CIRCULAR ORBIT, also including ATTRACTORS, INTERMITTENCY, NOISE, CHAOS, POWER LAW, FREQUENCY DOMAIN, TIME DOMAIN, SYSTEM DYNAMICS, POINCARE MAPS, PHASE PLANE, PHASE PORTRAITS) – focuses on application of chaos metrics/ tools (Lyapunov exponents, power spectra, correlation dimension, fractals) to time series, especially from heart and brain wave generators, to fully characterize the nonlinear dynamical components of the signal.

Factor 7 (SCALING, MODULATION EQUATIONS, NORMAL FORMS, PARAMETRIC EXCITATION, LINEAR ANALYSIS, LAGRANGIAN, HOMOCLINIC, FLOQUET THEORY, also including BIFURCATIONS, STABILITY, LIMIT CYCLES, PERIOD DOUBLING, INTERMITTENCY, HOMOCLINIC ORBITS, DUFFING OSCILLATOR) –

focuses on use of multiple scales to derive modulation equations (mainly Ginzburg-Landau equations expressing time variation of amplitude and phase), in standard normal form of low co-dimension bifurcations.

Factor 8 (VISCOSITY, WEAKLY NONLINEAR ANALYSIS, FLUID DYNAMICS, SURFACE TENSION, REYNOLDS NUMBERS, ANGULAR VELOCITY, GLOBAL EXISTENCE, PATTERN FORMATION, FREE SURFACE, STEADY-STATE, SHEAR, also including STABILITY, FREQUENCY DETUNING, AMPLITUDE EQUATIONS, FREQUENCY DOMAIN, TIME DOMAIN,) – focuses on dynamics of fluids where viscosity and surface tension are important (fluid-fluid and fluid-surface interactions, as well as some cases of free-surfaces). Examines stability and pattern formation as functions of different dimensionless parameters (Reynolds Numbers, Weber Number, Bond Number).

Factor 9 (CHAOS, NEURAL NETWORKS, NEURONS, MAPS, COMPLEX SYSTEMS, also including POINCARE MAPS, LIMIT CYCLES, TIME EVOLUTION, STATISTICAL PROPERTIES, ATTRACTORS, SYNCHRONIZED, LORENZ SYSTEM, LYAPUNOV EXPONENTS, CONTROLS, PHASE SPACE, INITIAL CONDITIONS, CHAOTIC DYNAMICS, STATE SPACE, LOCAL DYNAMICS) – focuses on nonlinear dynamics of coupled neurons in complex networks, emphasizing the use of coupled maps exhibiting chaotic oscillations to simulate the network behavior.

Factor 10 (ANGULAR MOMENTUM, TOTAL ENERGY, POWER LAW, NATURAL FREQUENCY, LOCAL MINIMA, FLUCTUATIONS, VORTICITY, also including CLASSICAL SYSTEM, TRACE FORMULA, STATISTICAL PROPERTIES, QUANTUM-CLASSICAL CORRESPONDENCE, TOPOLOGY) – focuses on major integrals of motion of interacting systems described by power law distribution spectra, especially in the transition regime between integrability and chaos.

Factor 11 (EXTERNAL DISTURBANCES, CONTROLS, PARAMETRIC UNCERTAINCIES, SYSTEM RESPONSE, FRICTION, NONLINEAR DYNAMICAL SYSTEMS, MECHANICAL SYSTEMS, DYNAMIC RESPONSE, OPTIMAL CONTROL, NONLINEARITY, CLOSED-LOOP SYSTEM, CONSTANT VELOCITY, RELATIVE MOTION, DYNAMIC PROPERTIES, also including MODELS, SYSTEM PARAMETERS, NEURAL NETWORKS) – focuses on adaptive robust control of nonlinear dynamical systems subject to external disturbances and parametric uncertainties, with emphasis on mechanical systems such as robots and automobiles.

Factor 12 (HOMOCLINIC ORBITS, PERIODIC ORBITS, TOPOLOGY, PHASE SPACE, SCALAR FIELD, HAMILTONIAN SYSTEMS, CRITICAL POINTS, INITIAL CONDITIONS, ANISOTROPY, VECTOR FIELDS, SINGULARITY, INVARIANT SETS, CHAOTIC DYNAMICS, DUFFING OSCILLATOR, also including POINCARE MAPS, PHASE PLANE, ATTRACTORS, NORMAL FORMS, HOMOCLINIC, MAPS, SYSTEM DYNAMICS) – focuses on orbits for which the stable and unstable manifolds intersect, especially those accompanied at small values of the bifurcation parameter by the

existence of a countable set of periodic and an uncountable set of aperiodic solutions (i.e., chaotic structure) in the proximity of the homoclinic.

Factor 13 (DIFFUSION COEFFICIENT, HAUSDORFF DIMENSION, EQUILIBRIUM STATE, RELAXATION, COMPLEX PLANE, LONG-TIME BEHAVIOUR, FIELD LINES, TIME DEPENDENCE, also including EIGENFUNCTIONS, LYAPUNOV EXPONENTS, FRACTALS) – focuses on relations between transport coefficients and chaotic properties for systems relaxing to equilibrium, emphasizing the relation between the diffusion coefficient and the fractality (the Hausdorff Dimension and the Lyapunov exponent) of the hydrodynamic modes of transport.

Factor 14 (EXPONENTIAL DECAY, DECOHERENCE, TOPOLOGICAL ENTROPY, COHERENT STATES, CLOSED ORBITS, ESSENTIAL SPECTRUM, AMPLITUDE EQUATIONS, CONVERGENCE PROPERTIES, PROBABILITY DISTRIBUTIONS, PHASE TRANSITION, also including CLASSICAL SYSTEM, EIGENFUNCTIONS, MUTUAL INFORMATION) –. focuses on decoherence effects of environment and detectors on quantum systems, whose classical correspondents are chaotic, and relates the decay function of the decoherence effect to the purely exponential decay characteristic of chaotic motion.

Factor 15 (ENTROPY, MUTUAL INFORMATION, THERMODYNAMICS, SPEECH, LONG TIME, POPULATION DYNAMICS, CORRELATION FUNCTION, also including QUANTUM MECHANICS, CLASSICAL DYNAMICS, LYAPUNOV EXPONENTS, CORRELATION DIMENSIONS, MAPS, TOPOLOGICAL ENTROPY, QUANTUM DOTS) – focuses on the use of mutual information between random variables and information theory analogues of thermodynamic entropy to analyze system dynamics and time series, in order to indicate structure or correlation and quantify informatioon content.

Factor 16 (FREQUENCY DOMAIN, TIME DOMAIN, DIFFERENTIAL EQUATIONS, FOURIER, SYSTEM DYNAMICS, ASYMPTOTIC EXPANSION, LINEAR SYSTEMS, REAL TIME, PERIODICITY, STATE SPACE, DIFFERENCE EQUATIONS, also including LIMIT CYCLES, FIXED POINTS, COMPLEX BEHAVIOR, TRACE FORMULA, TIME SERIES, CONTROLS, CONVERGENCE PROPERTIES) – focuses on control of limit cycle oscillations in dynamical systems, emphasizing time series analyses (e.g., convolutions) in the time domain, then Fourier transforms of time series into frequency domain, and subsequent frequency domain analyses.

Thus, the 16 factors can be viewed as thrust areas constituting the lowest level taxonomy. Each factor contains one or more of the following elements: 1) Sub-system –specific (e.g., neurons); 2) System-specific (e.g., brain); 3) System-generic (e.g., biological systems); 4) Phenomenon (e.g., bifurcations). Thus, there are myriad ways to combine the factors, depending on which dominant characteristics are chosen. In practice, the aggregation methodology will depend on the application for the taxonomy. For example, if the taxonomy is used to identify participants for a comprehensive workshop on Nonlinear Dynamics sources, categorizing by phenomena would identify

e.g., mapping experts, while categorizing by system would identify e.g. laser experts. Selection of aggregation attributes would depend on the workshop objectives. Conversely, assume the taxonomy is used by a program manager to estimate global levels of effort in specific technologies, in order to identify technology areas of adequacy and deficiency. Then, categorizing by phenomena would identify e.g., mapping deficiencies, whereas categorizing by system would identify e.g., laser deficiencies.

The factors above were aggregated by phenomena, using the higher level categorical structuring described in the next section. The following hierarchical level taxonomy resulted (numbers in parenthesis are factor numbers from above).

The highest level taxonomy consists of:

IA-Chaotic Motion

IB-Nonlinear Systems Concepts not necessarily linked to Chaotic Motion

The next highest level taxonomy consists of:

IA1-Characteristics and analysis tools for chaotic systems
(1, 3, 4, 6, 12, 13)

IA2-Synchronization and control of coupled systems
(5, 9)

1B1-Analytic tools for nonlinear analysis of specific applications
(8, 11)

IB2-Methods to simplify solutions of high dimensional nonlinear equations
(2, 7, 10, 14, 15, 16)

ES-3D. Abstract Multi-Link Clustering Taxonomy

A symmetrical co-occurrence matrix of the 253 highest frequency high technical content phrases was generated. The matrix elements were normalized using the Equivalence Index (Eij=Cij^2/Ci*Cj, where Ci is the total occurrence frequency of the ith phrase, and Cj is the total occurrence frequency of the jth phrase, for the matrix element ij), and a multi-link clustering analysis was performed using the WINSTAT statistical package. The Average Linkage method was used. Three types of raw data output were generated by each clustering run: a dendogram, a table, and a taxonomy. These three types of data output are described in detail in Appendix 1. The final 253 phrase dendogram is shown in Appendix 8. A description of the final dendogram, and the aggregation of its branches into a taxonomy of categories, follows. The capitalized phrases in parentheses represent cluster boundary phrases for each category.

The 253 phrases in the dendogram are grouped into 26 clusters. These clusters form the lowest level of the taxonomy hierarchy. Each cluster is assigned a letter, ranging from A to Z. The cluster hierarchies are determined by the branch structure. Overall, there are two main branches (clusters). Starting from the phrase adjoining the 'distance' ordinate, the first main cluster (A-M) ranges from MODELS to COMPLEX SYSTEMS. The second main cluster (N-Z) ranges from NONLINEAR PHENOMENA to TIME INTERVALS. While the total dendogram reflects different aspects of nonlinear dynamics, the first cluster (A-M) covers different aspects of chaotic motion, while the second cluster (N-Z) covers nonlinear system concepts with no specified links to chaotic motion. Each of these large clusters will be divided and sub-divided into smaller clusters, and discussed.

Cluster (A-M) can be divided into clusters (A-I) and (J-M). Cluster (A-I) ranges from MODELS to LINEAR SYSTEMS, and cluster (J-M) ranges from OSCILLATORS to COMPLEX SYSTEMS. Cluster (A-I) focuses on general characteristics of, and tools used to analyze, chaotic systems, while cluster (J-M) focuses on the synchronization and control of coupled systems subject to noise and other external disturbances.

Cluster (N-Z) can be divided into clusters (N-V) and (W-Z). Cluster (N-V) ranges from NONLINEAR PHENOMENA to CHAOTIC INFLATION, and cluster (W-Z) ranges from PERIODIC ORBITS to TIME INTERVALS. Cluster (N-V) focuses on the use of analytical tools (Fokker-Plank equation, Galerkin method, finite element method) for the nonlinear analysis of specific applications (aircraft vorticity, earthquakes, fluid dynamics, speech), and cluster (W-Z) focuses on methods to simplify solutions of high dimensional nonlinear equations (e.g., correspondence of quantum and classical systems, power law approximations, time domain-frequency domain transforms).

Cluster (A-I) can be subdivided into clusters (A-F) and (G-I) Cluster (A-F) ranges from MODELS to SCALAR FIELD, and focuses on analysis tools for, and characteristics of, chaotic systems. Cluster (G-I) ranges from MAPS to LINEAR SYSTEMS, and incorporates phenomena associated with chaotic and non-chaotic systems. Each of these clusters can now be divided into its elemental clusters.

Cluater A (MODELS to LAGRANGIAN) focuses on stability of periodic systems, emphasizing onset and prediction of instabilities; models periodic motions of dynamic systems to identify bifurcations that alter the stability of fixed points into limit cycles; uses multiple scales to derive modulation equations (mainly Ginzburg-Landau equations expressing time variation of amplitude and phase), in standard normal form of low codimension bifurcations.

Cluster B (PERIODIC SOLUTIONS to CONTINUATION METHOD) focuses on stability analysis and routes to chaos, using bifurcation diagrams, reduced and normal forms of the Poincare map, phase portraits, as well as phase plane trajectories to plot the motions.

Cluster C (HOMOCLINIC ORBITS to CIRCULAR ORBITS) focuses on periodic solutions near the homoclinic orbit of the Duffing oscillator with small perturbations, and on the conditions under which chaotic orbits can occur.

Cluster D (CHAOS to MODULATION FREQUENCY) focuses on application of chaos metrics/ tools (Lyapunov exponents, power spectra, correlation dimension, fractals) to time series, especially from heart and brain wave generators, to fully characterize the nonlinear dynamical components of the signal.

Cluster E (ATTRACTORS to COUPLED CHAOTIC SYSTEMS) focuses on formation of riddled basins (every point in a chaotic attractor's basin has pieces of another attractor's basin arbitrarily nearby) and off-on intermittency by the loss of transverse stability of an invariant subspace containing a chaotic attractor; examines the effect of perturbation-induced symmetry-breaking on blowout-bifurcations (accompanying Lyapunov exponent sign reversal) that create riddled basins.

Cluster F (INITIAL CONDITIONS to SCALAR FIELD) focuses on system dynamical evolutions based on initial conditions, and examines the topology of local and global dynamics in the phase space.

Cluster G (MAPS to DYNAMICAL EVOLUTION) focuses on chaotic maps with an invariant measure, the conditions under which period doubling is present on the route to chaos, and the fractality of the chaotic attractor.

Cluster H (DYNAMIC PROPERTIES to STOCHASTIC) focuses on dynamic properties of periodic orbits and chaotic attractors, and includes the use of maps to allow calculations of the location and stabilities of the periodic points in the chaotic attractor.

Cluster I (DIFFERENTIAL EQUATIONS to LINEAR SYSTEMS) focuses on the equations used to describe dynamical systems, and on the parameter-dependent periodic windows in the chaotic motions in which non-chaotic motion may be found.

Cluster (J-M) can be divided into its elemental clusters.

Cluster J (OSCILLATORS to INFORMATION SIGNAL) focuses on synchronization of chaotic dynamical systems, especially optically coupled diode lasers with optical feedback, and examines synchronization robustness with respect to frequency detuning.

Cluster K (SYSTEM DYNAMICS to DETERMINISTIC DYNAMICS) focuses on dynamics of chaotic systems (especially biological) in the presence of noise, including noise-enhanced temporal regularity, leading to determination of the vector field of the chaotic dynamics.

Cluster L (CONTROLS to THEORETICAL MODEL) focuses on adaptive robust control of nonlinear dynamical systems subject to external disturbances and parametric uncertainties, with emphasis on mechanical systems such as robots and automobiles.

Cluster M (NEURAL NETWORKS to COMPLEX SYSTEMS) focuses on use of neural networks to simulate brain subsystems, and the impact of both neuron models and temporal and spatial correlations in neuronal activity on the simulation strength of the neural network.

Cluster (N-V) may be divided into its elemental clusters, and cluster (W-Z) may be divided into its elemental clusters.

Cluster N (NONLINEAR PHENOMENA to ENERGY TRANSFER) focuses on nonlinear phenomena in aircraft flight, such as limit cycle oscillations, and the role of flow-field vortices in these fluid-structure oscillatory phenomena.

Cluster O (QUASIPERIODIC to NORMAL MODES) focuses on solving for velocity distributions and other variables of continuum flows in bounded regions with surface friction, using the Galerkin integral approach to solve the equations; solving for velocity distributions and other variables of particle flows in unbounded regions with inter-particle friction, using the Fokker-Planck kinetic equations to solve the equations; solving for structural dynamic responses to relative motions induced by to earthquakes, using finite element techniques.

Cluster P (FLUID DYNAMICS to ESSENTIAL SPECTRUM) focuses on fluid dynamics of partially or fully unbounded flows at different Reynold's Numbers, where surface tension at the free surface tends to increase instabilities and the fluid viscosity tends to reduce instabilities; population dynamics (mainly smaller animal species), emphasizing self-organization and pattern formation.

Cluster Q (IONS to MULTIPLE SOLUTIONS) focuses on quantum dots (semiconductor nanoparticles) and their structural and interaction similarities to large molecules and ions; the use of mutual information between random variables and information theory analogues of thermodynamic entropy to analyze system dynamics and time series, in order to indicate structure or correlation and quantify information content.

Cluster R (CALCULATIONS to NONLINEAR EQUATIONS) focuses on flows in heated channels, and the onset of instabilities as a function of channel aspect ratio and Rayleigh Number.

Cluster S (MAGNETIC FIELDS to LONG-TIME BEHAVIOR) focuses on transport coefficients across and parallel to ambient magnetic field lines in turbulent flows, both in space and fusion-driven plasmas; dissipative fluid flow systems, with turbulent kinetic energy and shear; relations between transport coefficients and chaotic properties for systems relaxing to stationary states, emphasizing the relation between the diffusion

coefficient and the fractality (the Hausdorff Dimension and the Lyapunov exponent) of the hydrodynamic modes of diffusion.

Cluster T (STEADY STATE to SPATIAL DISTRIBUTION) focuses on steady-state CO oxidation over Pd or Pt catalysts, including regular, chaotic, or mixed mode reaction rate oscillations driven by mass transfer limitations or external parameter variations.

Cluster U (RESONANCES to CONSTITUTIVE EQUATIONS) focuses on linear approximations to constitutive rheological equations to study temporal evolution of stress and other interface phenomena, emphasizing interface phenomena resonances as a function of parameter variations.

Cluster V (GROUND STATE to CHAOTIC INFLATION) focuses on changes in ordering of layers of molecule-sized particles, as a function of temperature and film thickness; chaotic conditions for chaotic nature of radiation emitted from black hole candidates, and energy spectra of this radiation.

Cluster W (PERIODIC ORBITS to TOTAL ENERGY) focuses on trace formulas, which in general relate the density of states for a given quantum mechanical system to the properties of the periodic orbits of its classical counterpart (quantum-classical correspondence); potential links between the statistical distribution of the energy levels of classically chaotic systems and the eigenvalue correlations of random matrix theory, or between the quantum properties of individual deterministically chaotic systems and of ensembles of randomly disordered systems; major integrals of motion of interacting systems described by power law distribution spectra, especially in the transition regime between integrability and chaos.

Cluster X (BOUNDARY CONDITIONS to DECOHERENCE) focuses on the influence of boundary conditions on the evolution of coherent structures in pattern formation, using the Ginzburg-Landau form of the amplitude equations.

Cluster Y (TIME DOMAIN to OPTIMAL CONTROL) focuses on control of limit cycle oscillations in dynamical systems, emphasizing time series analyses (e.g., convolutions) in the time domain, then Fourier transforms of time series into frequency domain, and subsequent frequency domain analyses; also establishes optimal control conditions for pertubed systems using ergodicity assumptions.

Cluster Z (SYMBOLIC DYNAMICS to TIME INTERVALS) focuses on decoherence effects of environment and detectors on quantum systems, whose classical correspondents are chaotic, and relates the decay function of the decoherence effect to the purely exponential decay characteristic of chaotic motion; use of topological methods to support symbolic dynamics, show existence of closed orbits, and estimate topological entropy.

ES-4. USA/ China Technical Emphasis Comparison.

The bibliometrics results showed that China's ranking as a prolific producer of nonlinear dynamics' research papers increased substantially over the past decade. It might be useful to identify their technology focus areas. In particular, it would be interesting to identify some technology areas in nonlinear dynamics in which the U. S. is a major player and China a minor player, and vice versa.

A non-symmetric Abstract phrase-country matrix was generated using the Abstract phrases and countries generated by the ACCESS template. All the countries were included, and Abstract phrases with a frequency of three or greater were included. The matrix elements' values reflected the number of records in which Abstract phrase x co-occurred with country y.

Only the columns for China and the USA were analyzed. The raw data phrases in the China column were normalized (multiplied by approximately three), such that the total number of China's 2001 records was set equal to the total number of USA 2001 records. The phrases in these two columns were compared, and the ratio of record frequencies for China's phrases to those of the USA was used as a comparison metric. This ratio ranged from infinity (finite occurrences in the China column, zero occurrences in the USA column) to zero (zero occurrences in the China column, finite occurrences in the USA column. The number of phrases in the different bands of the comparison metric is shown in Table 11.

TABLE 11 – RATIO OF RECORDS WITH SELECTED PHRASES IN NONLINEAR DYNAMICS CHINA/ USA LITERATURE – 2001

METRIC BAND	# PHRASES
INFINITY	1238
9 TO 25	138
.11 TO 9	7057
.05 TO .11	34
0	10686

There were a total of 19153 candidate phrases. For the present purpose of identifying major asymmetries, only the phrases with very high or very low record frequency ratios (the wings of the distribution function) were examined. Of this subset, only the phrases above a threshold of record frequencies were considered.

Table 12 contains phrases that met the numeric criteria (above), appeared to be significant technically, and, for the USA-predominant phrases in particular, appeared to be part of a pattern.

TABLE 12 – PHRASES WITH VERY HIGH OR LOW CHINA/ USA RECORD FREQUENCY RATIOS

	CHINA	**CHINA**	**RATIO**

PHRASE	RAW-DATA	USA	NORM	CH/ US
WEAK EXTERNAL NOISE	3	0	9.17	INF
DUAL-RING LASER	3	0	9.17	INF
ERBIUM-DOPED FIBER	3	0	9.17	INF
EXTERNAL NOISE	8	1	24.45	24.45
NOISE INTENSITY	6	1	18.34	18.34
GAUSSIAN WHITE NOISE	3	1	9.17	9.17
SEISMIC	1	18	3.06	0.17
NAVIER-STOKES	1	22	3.06	0.14
SEA	1	24	3.06	0.13
VORTICITY	1	25	3.06	0.12
MAGNETIC	3	76	9.17	0.12
SOLAR	1	26	3.06	0.12
OCEAN	1	29	3.06	0.11
SEMICONDUCTOR	1	32	3.06	0.10
MAGNETIC FIELD	0	51	0	0
FRONTS	0	20	0	0
ORBITAL	0	16	0	0
BOUNDARY LAYER	0	16	0	0
PACIFIC	0	15	0	0
BROWNIAN	0	15	0	0
AERODYNAMIC	0	15	0	0
CURRENTS	0	13	0	0
MAGNETIC FIELDS	0	13	0	0
MAGNETOHYDRODYNAMIC	0	13	0	0
SEMICONDUCTOR LASERS	0	12	0	0
AIRCRAFT	0	12	0	0
AEROELASTIC	0	12	0	0
ICE	0	12	0	0
RAYLEIGH NUMBER	0	11	0	0
ENCODING	0	11	0	0
GALAXIES	0	10	0	0
BROWNIAN MOTION	0	9	0	0
NINO	0	8	0	0
STELLAR	0	8	0	0
BLACK HOLE	0	8	0	0
DIELECTRIC	0	8	0	0
EL NINO	0	8	0	0
MESOSCALE	0	8	0	0
SEDIMENT	0	7	0	0

SEMICONDUCTOR LASER	0	7	0	0
TROPOSPHERE	0	7	0	0
DECODING	0	7	0	0
BLACK HOLES	0	7	0	0
GALACTIC	0	7	0	0
TELESCOPE	0	6	0	0
BAROTROPIC	0	6	0	0
DEEP WATER	0	6	0	0
SEDIMENTS	0	5	0	0
SHALLOW-WATER	0	5	0	0
TRANSONIC	0	5	0	0
TROPOSPHERIC	0	5	0	0
WATER DEPTH	0	5	0	0
WIND-TUNNEL	0	5	0	0
ASTROPHYSICAL	0	5	0	0
ANGLE OF ATTACK	0	5	0	0
INTERSTELLAR	0	5	0	0
GALAXY	0	5	0	0

In Table 12, the leftmost column is the phrase of interest, the next column is number of China records in which the phrase appears, the next column is number of USA columns in which the phrase appears, the next column is the normalized China column, and the rightmost column is the ratio of the normalized China column matrix element to the USA column matrix element. The distribution in Table 12, as well as in the raw data, is asymmetric. There are many more phrases that appear predominately in USA records than predominately in China records.

The first six phrases in Table 12 are those that predominate in China records. The only pattern appears to focus on noise. While the phrase NOISE is about equally distributed between China and USA records in the raw data, some variants predominated in the China records, as shown in Table 12.

The remainder of the phrases in Table 12 are those that predominate in USA records. Perhaps the most surprising is MAGNETIC FIELD(S). For the 2001 database, there are 64 USA records that contained MAGNETIC FIELD(S), and no China records. A sampling of these USA records showed them to be of two generic types. The dominant type addressed the nonlinear dynamics of magnetic fields in space plasmas, and the other type addressed the nonlinear dynamics of magnetic fields in controlled magnetic fusion systems. These applications areas require large experimental and flight facilities to conduct research and obtain data. The USA has large efforts in both areas, whereas China has minimal efforts in both. Other USA-dominant phrases from Table 12 related to space research support this reasoning (SOLAR, GALAXIES, STELLAR, BLACK HOLE(S), TROPOSPHERE, GALACTIC, TELESCOPE, ASTROPHYSICAL, INTERSTELLAR, GALAXY).

Two major caveats on the data in Table 12 should be emphasized. First, only phrases above the threshold frequency were considered for the candidate phrase pool. Thus, phrases that have zero frequency in Table 12 could in fact have a very low, but finite, frequency. Second, the phrases for the co-occurrence computations were restricted to the Abstracts only. Thus, phrases that occurred in the Keywords or Title were not included.

Other topical areas with patterns of USA predominance include oceanography and weather (SEA, OCEAN, FRONTS, PACIFIC, ICE, EL NINO, MESOSCALE, SEDIMENT, BAROTROPIC, DEEP WATER, SHALLOW-WATER, WATER DEPTH), aerodynamics (NAVIER-STOKES, VORTICITY, BOUNDARY LAYER, AERODYNAMIC, AIRCRAFT, AEROELASTIC, WIND-TUNNEL, ANGLE OF ATTACK), semiconductors (SEMICONDUCTOR, SEMICONDUCTOR LASER (S)), and encryption (ENCODING, DECODING). In fact, perusal of the lower frequency raw data terms relating to coding shows almost no phrases in any of the variants in the China literature. Again, many of the oceanography/ weather-related papers reflect large-scale experimental programs, from which more data would be available to a developed nation than a developing nation.

Because of the two caveats on the numbers in Table 12 presented previously, the phrases discussed above that reflected areas of USA dominance relative to China were inserted into the SCI, to validate the results. All the fields were examined, <u>with no threshold</u> on phrase frequency. The USA still predominated heavily, by a factor of about five relative to the normalized China frequencies. Thus, the simple method presented here provides the correct order of magnitude answer, but the actual ratio values are overly <u>optimistic</u>. In fact, this combination of using the simple method to identify major technical emphasis differences between countries, followed by a more targeted and detailed analysis of the SCI, is probably a reasonable prototype for a production-level analysis.

While these examples and the associated analysis are very abbreviated due to space limitations, the capability offered is intrinsically very powerful. The high frequency phrase/ low frequency phrase relational technique allows a microcasm of the total text mining study to be performed for any high frequency phrase, or combination of high frequency phrases. When relational indicators are used (not shown in this example), tens, or even hundreds, of low frequency phrases can be identified as relating to a high frequency phrase (depending on the total number of phrases used, and the threshold values of the numerical relational indicators chosen). These low frequency phrases can be categorized into a taxonomy, allowing the technical and bibliometric infrastructure for the high frequency phrase/ concept to be obtained.

ES-5. Observations on Results

This section addresses balance or imbalance of Nonlinear Dynamics with respect to different parameters.

A) Type of Research

In contrast to many of the previous topical text mining studies performed, Nonlinear Dynamics appears to be balanced among theory, experiment, and computational modeling. There is substantial phrase representation in all these research segments.

B) Categories of Research

Compared to most text mining studies performed previously by the first author, Nonlinear Dynamics seems heavily weighted toward basic research. No applied research journals were evident. No companies appeared in the institutional production category, and the only industry appearance was reflected by one of the most cited authors.

However, given the large volume of research activity, the discipline appears poised to transition into applications. There is already ongoing work on antennas, detectors, thermal combustors, and high power lasers that should find its way eventually to industry. The six volumes of experimental papers (not contained in the SCI) from the Proceedings of the Experimental Chaos conference (18-23) provide some indication of the breadth of potential applications.

C) Applications vs Tech Base

There appears to be a reasonable balance between generic tech base studies and more focused areas. Based on the journals and author institutions as stated above, as well as the types of phrases obtained, the focused area studies are more at the basic research level than applied.

Overall, there is a reasonable balance between chaos-oriented phenomena and nonlinear phenomena with no specified links to chaotic motion. Further, there appears to be a reasonable balance among techniques for analyzing chaotic systems, techniques for synchronizing and controlling coupled systems, and use of analytical tools for the nonlinear analysis of specific applications. Progress on methods to simplify solutions of high dimensional nonlinear equations, or on spatio-temporal (infinite dimensional) systems, has been slower.

Within the tech base areas, the priorities seem reasonable. Major emphasis is given to stability and cycling, reasonable emphasis is given to motion, scaling, modeling and simulation, and moderate emphasis is given to communication, control, coupling, thermodynamics, structures, and experiment. Hard divisions among many of these categories are somewhat blurred, because of overlap and potential multiple category assignment of phrases.

Within the focused areas, there is a reasonable balance among physical, environmental, engineering, and life sciences. However, there is a substantial imbalance between the ‘hard’ and ‘soft’ sciences. Essentially nothing in the phrase pattern analysis reflected input from the true social and political sciences. The number of articles retrieved from the Social Science Citation Index was four percent of the total articles retrieved. A reading of these ‘social science’ articles showed that: 1) ‘chaos’ is used in the vernacular in a not-insignificant fraction; 2) neuroscience and psychiatry/

psychology have reasonable representation, but they were captured in the phrase pattern analysis; 3) there is some effort on financial markets, but too widespread to generate high or mid-frequency phrase outputs; 4) there is minimal effort in the true social and political sciences.

One objective of the present study was to understand the applicability of Nonlinear Dynamics to political trends and predictions. Because chaos applies to deterministic equations, its applications to social systems are problemmatical, since social systems are too noisy to define deterministic trajectories. Too much information is missing in social/ economic systems to model the system accurately enough to find chaos, although other nonlinear responses are apparent. For example, the stock market has dramatic changes, and WWI started over a single assassination.

The documented applications in these social science areas are minimal. There may be a variety of causes in addition to noisy data mentioned above. In the present high tech world economy, both commercial and military, research sponsoring organizations may be far more interested in pursuing 'hard' science applications of Nonlinear Dynamics than 'soft' science applications.

Thus, money for social and political science research in Nonlinear Dynamics may not be available. In addition, because of potential sensitivities of political and social structure dynamics and trends, Nonlinear Dynamics studies may in fact be ongoing, but not published in the open literature. Given the inherent strong feedback and non-linearities in social group situations and organizations at all levels, one would expect that Nonlinear Dynamics could provide useful insights for analyzing and predicting social and political trends.

At a minimum, some of the concepts of Nonlinear Dynamics may be useful to 'softer' science applications, including bifurcations of behaviors, extreme sensitivity to initial conditions, pattern formation, attractors, repellers, and orbits. For example, there is an effort at ONR in war gaming based on cellular automata that has aspects of pattern formation (complexity) arising from simple rules. Flanking maneuvers appear, but have not been explicitly programmed. For all practical purposes, applicability of Nonlinear Dynamics to the 'softer' sciences remains unexplored.

D) Regional

Most previous text mining studies have shown the USA to be dominant in research output, and the Nonlinear Dynamics study is no exception. However, the difference between the USA and the other producers appears to be greater. This imbalance has been reduced over the past decade, from a factor of four greater than its nearest competitor to a factor of three, but it is still substantial. China has ascended as a major competitor, but does not appear to be involved in major areas in which the USA is not working. There is a reasonable balance between Europe and Asia, but still a substantial under-representation from the developing nations.

ES-6. Final Observations

The different statistical and non-statistical taxonomies generated above used different methodologies and some different phrases. Therefore, the results are not directly comparable. A taxonomy that reflects the levels of effort and specific research thrusts would have the structure of the non-statistical Abstract field taxonomy. A taxonomy that reflects commonality of categories would have the structure of the statistical taxonomies.

This paper has presented a number of advantages of using DT and bibliometrics for deriving technical intelligence from the published literature. Large amounts of data can be accessed and analyzed, well beyond what a finite group of expert panels could analyze in a reasonable time period. Preconceived biases tend to be minimized in generating roadmaps. Compared to standard co-word analysis, DT uses full text, not index words, and can make maximum use of the rich semantic relationships among the words. It also has the potential of identifying low occurrence frequency but highly theme related phrases that are 'needles-in-a-haystack', a capability unavailable to any of the other co-occurrence methods.

Combined with bibliometric analyses, DT identifies not only the technical themes and their relationships, but relationships among technical themes and authors, journals, institutions, and countries. Unlike other roadmap development processes, DT generates the roadmap in a 'bottom-up' approach. Unlike other taxonomy development processes, DT can generate many different types of taxonomies (because it uses full text, not key words) in a 'bottom-up' process, not the typical arbitrary 'top-down' taxonomy specification process. Compared to co-citation analysis, DT can use any type of text, not only published literature, and it is a more direct approach to identifying themes and their relationships.

The maximum potential of the DT and bibliometrics combination can be achieved when these two approaches are combined with expert analysis of selected portions of the database. If a manager, for example, wants to identify high quality research thrusts as well as science and technology gaps in specific technical areas, then an initial DT and bibliometrics analysis will provide a contextual view of work in the larger technical area; i.e., a strategic roadmap. With this strategic map in hand, the manager can then commission detailed analysis of selected abstracts to assess the quality of work done as well as identify work that needs to be done (promising opportunities).

1. INTRODUCTION

Science and technology are assuming an increasingly important role in the conduct and structure of domestic and foreign business and government. In the highly competitive civilian and military worlds, there has been a commensurate increase in the need for scientific and technical intelligence to insure that one's perceived adversaries do not gain an overwhelming advantage in the use of science and technology. While there is no substitute for direct human intelligence gathering, there have become available many techniques that can support and complement it. In particular, techniques that identify, select, gather, cull, and interpret large amounts of technological information semi-automatically can expand greatly the capabilities of human beings in performing technical intelligence.

One such technique is DT (2, 3, 4), a system for analyzing large amounts of textual computerized material. It includes algorithms for extracting multi-word phrase frequencies and phrase proximities from the textual databases, coupled with the topical expert human analyst to interpret the results and convert large volumes of disorganized data to ordered information. Phrase frequency analysis (occurrence frequency of multi-word technical phrases) provides the pervasive technical themes of a database, and the phrase proximity (physical closeness of the multi-word technical phrases) analysis provides the relationships among pervasive technical themes, as well as among technical themes and authors/journals/institutions/countries, etc. The present paper describes use of the DT process, supplemented by literature bibliometric analyses, to derive technical intelligence from the published literature of Nonlinear Dynamics science and technology.

Nonlinear Dynamics, as defined by the authors for this study, is that class of motions in deterministic physical and mathematical systems whose time evolution has a sensitive dependence on initial conditions. Since one of the key outputs of the present study is a query that can be used by the community to access relevant Nonlinear Dynamics documents, a recommended query based on this study is presented in total. This query serves as the operational definition of Nonlinear Dynamics, and its development is discussed in detail in the database generation section.

<u>NONLINEAR DYNAMICS QUERY</u>

((CHAO* AND (SYSTEM* OR DYNAMIC* OR PERIODIC* OR NONLINEAR OR BIFURCATION* OR MOTION* OR OSCILLAT* OR CONTROL* OR EQUATION* OR FEEDBACK* OR LYAPUNOV OR MAP* OR ORBIT* OR ALGORITHM* OR HAMILTONIAN OR LIMIT* OR QUANTUM OR REGIME* OR REGION* OR SERIES OR SIMULATION* OR THEORY OR COMMUNICATION* OR COMPLEX* OR CONVECTION OR CORRELATION* OR COUPLING OR CYCLE* OR DETERMINISTIC OR DIMENSION* OR DISTRIBUTION* OR DUFFING OR ENTROPY OR EQUILIBRIUM OR FLUCTUATION* OR FRACTAL* OR INITIAL CONDITION* OR INVARIANT* OR LASER* OR LOGISTIC OR LORENZ OR MAGNETIC FIELD* OR MECHANISM* OR MODES OR NETWORK* OR ONSET OR TIME OR FREQUENC*

OR POPULATION* OR STABLE OR ADAPTIVE OR CIRCUIT* OR DISSIPAT* OR EVOLUTION OR EXPERIMENTAL OR GROWTH OR HARMONIC* OR HOMOCLINIC OR INSTABILIT* OR OPTICAL)) OR (BIFURCATION* AND (NONLINEAR OR HOMOCLINIC OR QUASIPERIODIC OR QUASI-PERIODIC OR DOUBLING OR DYNAMICAL SYSTEM* OR EVOLUTION OR INSTABILIT* OR SADDLE-NODE* OR MOTION* OR OSCILLAT* OR TRANSCRITICAL OR BISTABILITY OR LIMIT CYCLE* OR POINCARE OR LYAPUNOV OR ORBIT*)) OR (NONLINEAR AND (PERIODIC SOLUTION* OR OSCILLAT* OR MOTION* OR HOMOCLINIC)) OR (DYNAMICAL SYSTEM* AND (NONLINEAR OR STOCHASTIC OR NON-LINEAR)) OR ATTRACTOR* OR PERIOD DOUBLING* OR CORRELATION DIMENSION* OR LYAPUNOV EXPONENT* OR PERIODIC ORBIT* OR NONLINEAR DYNAMICAL) NOT (CHAO OR CHAOBOR* OR CHAOTROP* OR CAROTID OR ARTERY OR STENOSIS OR PULMONARY OR VASCULAR OR ANEURYSM* OR ARTERIES OR VEIN* OR TUMOR* OR SURGERY)

To execute the study reported in this paper, a database of relevant Nonlinear Dynamics articles is generated using the iterative search approach of Simulated Nucleation (5, 6). Then, the database is analyzed to produce the following characteristics and key features of the Nonlinear Dynamics field: recent prolific Nonlinear Dynamics authors; journals that contain numerous Nonlinear Dynamics papers; institutions that produce numerous Nonlinear Dynamics papers; keywords most frequently specified by the Nonlinear Dynamics authors; authors, papers and journals cited most frequently; pervasive technical themes of Nonlinear Dynamics; and relationships among the pervasive themes and sub-themes.

What is the importance of applying DT and bibliometrics to a topical field such as Nonlinear Dynamics? The roadmap, or guide, of this field produced by DT and bibliometrics provides the demographics and a macroscopic view of the total field in the global context of allied fields. This allows specific starting points to be chosen rationally for more detailed investigations into a specific topic of interest. DT and bibliometrics do not obviate the need for detailed investigation of the literature or interactions with the main performers of a given topical area in order to make a substantial contribution to the understanding or the advancement of this topical area, but allow these detailed efforts to be executed more efficiently. DT and bibliometrics are quantity-based measures (number of papers published, frequency of technical phrases, etc.), and correlations with intrinsic quality are less direct. The direct quality components of detailed literature investigation and interaction with performers, combined with the DT and bibliometrics analysis, can result in a product highly relevant to the user community.

2. BACKGROUND

2.1 Overview

The information sciences background for the approach used in this paper is presented in (7). This reference shows the unique features of the computer and co-word-based DT process relative to other roadmap techniques. It describes the two main roadmap categories (expert-based and computer-based), summarizes the different approaches to computer-based roadmaps (citation and co-occurrence techniques), presents the key features of classical co-word analysis, and shows the evolution of DT from its co-word roots to its present form.

The DT method in its entirety requires generically three distinct steps. The first step is identification of the main themes of the text being analyzed. The second step is determination of the quantitative and qualitative relationships among the main themes and their secondary themes. The final step is tracking the evolution of these themes and their relationships through time. The first two steps are summarized in 2.1.1 and 2.1.2. . Time evolution of themes has not yet been studied.

At this point, a variety of different analyses can be performed. For databases of non-journal technical articles (2), the final results have been identification of the pervasive technical themes of the database, the relationship among these themes, and the relationship of supporting sub-thrust areas (both high and low frequency) to the high-frequency themes. For the more recent studies in which the databases are journal article abstracts and associated bibliometric information (authors, journals, addresses, etc), the final results have also included relationships among the technical themes and authors, journals, institutions, etc (7-11).

2.1.1. First Step

The frequencies of appearance in the total text of all single word phrases (e.g., Matrix), adjacent double word phrases (e.g., Metal Matrix), and adjacent triple word phrases (e.g., Metal Matrix Composites) are computed. The highest frequency significant technical content phrases are selected by topical experts as the pervasive themes of the full database.

2.1.2. Second Step

2.1.2.1. Numerical Boundaries

For each theme phrase, the frequencies of phrases within +/-M (nominally 50) words of the theme phrase are computed for every occurrence of the theme phrase in the full text, and a phrase frequency dictionary is constructed. This dictionary contains the phrases closely related to the theme phrase. Numerical indices are employed to quantify the strength of this relationship. Both quantitative and qualitative analyses are performed by the topical expert for each dictionary (hereafter called cluster) yielding,

among many results, those sub-themes closely related to and supportive of the main cluster theme.

Threshold values are assigned to the numerical indices, and these indices are used to filter out the phrases most closely related to the cluster theme. However, because numbers are limited in their ability to portray the conceptual relationships among themes and sub-themes, the qualitative analyses of the extracted data by the topical experts have been at least as important as the quantitative analyses. The richness and detail of the extracted data in the full text analysis allow an understanding of the theme inter-relationships not heretofore possible with previous text abstraction techniques (using index words, key words, etc.).

2.1.2.2. Semantic Boundaries

The approach is conceptually similar to 2.1.2.1, with the difference being that semantic boundaries are used to define the co-occurrence domain rather than numerical boundaries. The only semantic boundaries used for the present studies were paper Abstract boundaries. Software is being developed that will allow paragraphs or sentences to be used as semantic boundaries.

It is an open question as to whether semantic boundaries or numerical boundaries provide more accurate results. The elemental messages of text are contained in concepts or thoughts. Sentences or paragraphs are the vehicles by which the concepts or thoughts are expressed. The goal of text mining is to usually quantify relationships occurring in the concepts or thoughts, not in the fragments of their vehicles of expression. In particular, while intra-sentence relationships will be very strong, they may be overly restrictive for text mining purposes, and many cross-discipline relationships can be lost by adhering to intra-sentence relationships only. Intra-paragraph relationships are more inclusive and reasonable. For journal paper Abstracts of the type found in SCI, many Abstracts constitute a single paragraph.

2.2 Unique Study Features

The study reported in the present paper is in the latter (journal article abstract) category. It differs from the previous published papers in this category (7-11) in five respects. First, the topical domain (Nonlinear Dynamics) is completely different. Second, a much more rigorous statistically-based technical theme clustering approach is used. Third, bibliometric clustering is presented for two database fields: authors and countries. Fourth, a combination of fuzzy logic and manual aggregation was used in phrase selection to consolidate similar phrases, thereby allowing additional phrases to be used in the clusters and increase the scope of the clusters. Finally, the marginal utility algorithm was applied for the first time, allowing only the highest payoff terms to be included in the final query, and resulting in an efficient query.

3. DATABASE GENERATION

The key step in the Nonlinear Dynamics literature analysis is the generation of the database to be used for processing. There are three key elements to database generation: the overall objectives, the approach selected, and the database used. Each of these elements is described.

3.1 Overall Study Objectives

The main objective was to identify global S&T that had both direct and indirect relations to Nonlinear Dynamics. A sub-objective was to estimate the overall level of global effort in Nonlinear Dynamics S&T, as reflected by the emphases in the published literature.

3.2 Databases and Approach

For the present study, the SCI database was used. The approach used for query development was the DT-based iterative relevance feedback concept (5).

3.2.1 Science Citation Index/ Social Science Citation Index (12)

The retrieved database used for analysis consists of selected journal records (including the fields of authors, titles, journals, author addresses, author keywords, abstract narratives, and references cited for each paper) obtained by searching the Web version of the SCI for Nonlinear Dynamics articles. At the time the final data was extracted for the present paper (early 2002), the version of the SCI used accessed about 5600 journals (mainly in physical, engineering, and life sciences basic research) from the Science Citation Index, and over 1700 journals from the Social Science Citation Index. There is some overlap among the journals. For example, for 2001, there were 999620 total articles in the Science Citation Index, 149672 articles in the Social Sciences Citation Index, and 1104275 articles in the combined databases. Thus, 45017 articles were shared by both databases, four percent of the total, but thirty percent of the Social Science Citation Index.

The SCI database selected represents a fraction of the available Nonlinear Dynamics (mainly research) literature, that in turn represents a fraction of the Nonlinear Dynamics S&T actually performed globally (13). It does not include the large body of classified literature, or company proprietary technology literature. It does not include technical reports or books or patents on Nonlinear Dynamics. It covers a finite slice of time (1991, 2001). The database used represents the bulk of the peer-reviewed high quality Nonlinear Dynamics research literature, and is a representative sample of all Nonlinear Dynamics research in recent times.

To extract the relevant articles from the SCI, the Title, Keyword, and Abstract fields were searched using Keywords relevant to Nonlinear Dynamics. The resultant Abstracts were culled to those relevant to Nonlinear Dynamics. The search was

performed with the aid of two powerful DT tools (multi-word phrase frequency analysis and phrase proximity analysis) using the process of Simulated Nucleation (5).

An initial query of Nonlinear Dynamics-related terms produced two groups of papers: one group was judged by domain experts to be relevant to the subject matter, the other was judged to be non-relevant. Gradations of relevancy or non-relevancy were not considered. An initial database of Titles, Keywords, and Abstracts was created for each of the two groups of papers. Phrase frequency and proximity analyses were performed on this textual database for each group. The high frequency single, double, and triple word phrases characteristic of the relevant group, and their boolean combinations, were then added to the query to expand the papers retrieved. Clustering of phrases into thematic categories was performed to help guide the selection of phrases (See Appendix 1 for a description of some of the clustering approaches). Phrases from each of the thematic categories were selected to insure balanced representation from the complete sample of relevant records. Similar phrases characteristic of the non-relevant group were effectively subtracted from the query to contract the papers retrieved. The process was repeated on the new database of Titles, Keywords, and Abstracts obtained from the search. A few more iterations were performed until the number of records retrieved stabilized (convergence). The final phrase-based query used for the Nonlinear Dynamics study was shown in the Introduction.

In order to generate an efficient final query, a new process termed Marginal Utility was applied. At the start of the final iteration, a modified query (Q1-See Appendix 2) was inserted into the SCI, and records were retrieved. A sample of these records was then categorized into relevant and non-relevant. Each term in Q1 was inserted into the Marginal Utility algorithm, and the marginal number of relevant and non-relevant records in the sample that the query term would retrieve was computed (see Appendix 2 for these numerical indicators). Only those terms that retrieved a high ratio of relevant to non-relevant records were retained. Since (by design) each query term had been used to retrieve records from the SCI as part of Q1, the marginal ratio of relevant to non-relevant records from the sample would represent the marginal ratio of relevant to non-relevant records from the SCI. The final efficient query Q2, consisting of the highest marginal utility terms, was shown in the Introduction.

In the Marginal Utility algorithm, terms that co-occur strongly in records with previously-selected terms are essentially duplicative from the retrieval perspective, and can be eliminated. Thus, the order in which terms are selected becomes important. In the manual selection process described here, the candidate query terms were ordered by occurrence frequency, and tested for Marginal Utility. This may not be the most efficient use of Marginal Utility.

An automated query term selection algorithm using Marginal Utility is being developed presently. In the automated approach, all the terms in Q1 would be inserted into the Marginal Utility algorithm. The highest relevant frequency term (T1) would be selected first. Then, the Marginal Utility of every other term would be examined, in conjunction with only the first term selected. The term that retrieved the most marginal relevant

records (T2), above a pre-specified floor of relevant to non-relevant record ratio, would be added to the query. At this point, the query would consist of terms T1 and T2. Then, the Marginal Utility of every other term would be examined, in conjunction with only the first two terms selected. The same process that was used to select T2 would be used to select T3. This recursive process would be continued until either a pre-specified limit on total number of query terms, or the floor ratio of relevant records to non-relevant records retrieved, was reached.

The authors believe that queries of these magnitudes and complexities are required when necessary to provide a tailored database of relevant records that encompasses the broader aspects of target disciplines. In particular, if it is desired to enhance the transfer of ideas across disparate disciplines, and thereby stimulate the potential for innovation and discovery from complementary literatures (1), then even more complex queries using Simulated Nucleation may be required.

However, even with queries of this magnitude, not all records will be retrieved. As a point of reference, there were 204 articles with Abstracts published in the International Journal of Bifurcation and Chaos in 2001, of which 164 (~80%) were retrieved for this study. This was the highest fraction retrieved for any journal examined. For all the journals examined, some records have insufficient verbiage in their text fields, or have very non-standard verbiage relative to the main topical themes, such that they will not match with the query. These records are not retrieved. To retrieve records with non-standard very low frequency terminology from all the journals accessed would require queries that contain thousands of terms. The reader should think about how many fewer Nonlinear Dynamics records would have been accessed with the typical search queries containing about a half dozen terms, and how author and journal citation rates are negatively impacted by the combination of insufficient queries and insufficient verbiage in the record text fields.

4. RESULTS

The results from the publications bibliometric analyses are presented in section 4.1, followed by the results from the citations bibliometrics analysis in section 4.2. Results from the DT analyses are shown in section 4.3. The SCI bibliometric fields incorporated into the database included, for each paper, the author, journal, institution, and Keywords. In addition, the SCI included references for each paper.

The bibliometrics sections (4.1, 4.2) have three components. Some numerical indicators are presented for each bibliometric examined. Clustering results, that portray cohesive groups, are presented for most prolific authors only. Finally, the highest frequency bibliometrics (e.g., most prolific author, most prolific country) are presented for each bibliometric, and discussed.

The DT sections contain three components. First, the high frequency Keywords are grouped into 'natural' categories, and the picture they provide of the Nonlinear Dynamics literature (research, open literature, unclassified, non-proprietary) is

described. Second, the high frequency phrases from the Abstracts are grouped into 'natural' categories, and the picture they provide of the Nonlinear Dynamics literature is presented. Third, the high numerical indicator phrases from the proximity analyses of the Abstracts and other portions of the database (author names, article titles, journal names, author addresses) are grouped into 'natural' categories, and the picture they provide of the Nonlinear Dynamics literature is shown. The meaning of the term 'natural' is that these categories were not prescribed beforehand. From observation of the hundreds of different phrases and their frequencies, categories useful for interpreting and describing the main literature findings appeared to emerge.

The analytical approaches taken for the first three components (Keyword phrase frequency, Abstract phrase frequency, Abstract phrase proximity) are based on their fundamental data structures. The Keyword and Abstract phrase frequencies are essentially quantity measures. They lend themselves to 'binning', and addressing adequacies and deficiencies in levels of effort. They do not contain relational information, and therefore offer little insight into S&T linkages.

The phrase proximity results are essentially relational measures, although some of the proximity results imply levels of effort that support specific S&T areas. The phrase proximity results mainly offer insight into S&T linkages, and have the potential to help identify innovative concepts from disparate disciplines (1). Thus, the Keyword and Abstract phrase frequency analyses will be addressed to adequacy of effort, and the phrase proximity analyses will be addressed to relationships primarily and supporting levels of effort secondarily.

4.1 Publication Statistics on Authors, Journals, Organizations, Countries

The first group of metrics presented is counts of papers published by different entities. These metrics can be viewed as output and productivity measures. They are not direct measures of research quality, although there is some threshold quality level inferred, since these papers are published in the (typically) high caliber journals accessed by the SCI.

4.1.1 Prolific Nonlinear Dynamics Authors

Previous DT/ bibliometrics studies were conducted of the technical fields of: 1) Near-earth space (NES) (8); 2) Hypersonic and supersonic flow over aerodynamic bodies (HSF) (7); 3) Chemistry (JACS) (9) as represented by the Journal of the American Chemical Society; 4) Fullerenes (FUL) (10); 5) Aircraft (AIR) (11); 6) Hydrodynamic flow over surfaces (HYD); 7) Electric power sources (EPS); and 8) the non-technical field of research impact assessment (RIA). Overall parameters of these studies from the SCI database results and the current Nonlinear Dynamics study are shown in Table 1. In addition, in the present study, only four percent of the total retrieved papers derived from the Social Sciences Citation Index. The remaining 96 percent derived from the Science Citation Index.

TABLE 1 - DT STUDIES OF TOPICAL FIELDS

TOPICAL AREA	NUMBER OF SCI ARTICLES	YEARS COVERED
1) NEAR-EARTH SPACE (NES)	5480	1993-MID 1996
2) HYPERSONICS (HSF)	1284	1993-MID 1996
3)CHEMISTRY (JACS)	2150	1994
4) FULLERENES (FUL)	10515	1991-MID 1998
5) AIRCRAFT (AIR)	4346	1991-MID 1998
6) HYDRODYNAMICS (HYD)	4608	1991-MID 1998
7) ELECTRIC POWER SOURCES (EPS)	20835	1991-BEG 2000
8) RESEARCH ASSESSMENT (RIA)	2300	1991-BEG 1995
9) NONLINEAR DYNAMICS (NONLIN)	6118	2001

These studies yielded: 1) 3.37 authors per paper for the NES results; 2) 2.63 authors per paper for the HSF results; 3) 3.79 authors per paper for the JACS results; 4) 3.92 authors per paper for the FUL results; 5) 2.09 authors per paper for the AIR results; 6) 2.29 authors per paper for the HYD results; and 7) 2.90 authors per paper for the EPS results. A previous study on the non-technical field of research impact assessment (RIA) (9) yielded about 1.68 authors per paper.

In the present Nonlinear Dynamics study, two types of computational linguistics analysis were performed on the author data field in the database. First, a frequency count of author appearances was made from the author field in the database, to identify the most prolific authors. Second, a clustering analysis was performed on the list of author appearances, to identify tightly-knit multi-author groups. The clustering methodology (also used in the analysis of the Abstract free text field to generate technology taxonomies) is described in Appendix 1.

4.1.1.1 Author Frequency Results

There were 6118 papers retrieved, 12136 different authors, and 16370 author listings. The occurrence of each author's name on a paper is defined as an author listing. While the average number of listings per author is about 1.34, the nineteen most prolific authors (see Table 2A) have listings more than an order of magnitude greater than the average. The number of papers listed for each author are those in the database of records extracted from the SCI using the query, not the total number of author papers listed in the source SCI database.

TABLE 2A – MOST PROLIFIC AUTHORS - 2001
(present institution listed)

AUTHOR	INSTITUTION	COUNTRY	#PAPERS
CHEN--GR	CITY UNIV HONG KONG	CHINA	24
LAI--YC	ARIZONA STATE	USA	21
NAYFEH--AH	VPI	USA	16
HU--G	CHINA CTR ADV S&T	CHINA	15

MOSEKILDE--E	TECH UNIV	DENMARK	15
XU--JX	XIAN JIAOTONG UNIV	CHINA	14
AIHARA--K	UNIV TOKYO	JAPAN	13
GASPARD--P	FREE UNIV BRUSSELS	BELGIUM	12
ZHENG--ZG	BEIJING NORMAL UNIV	CHINA	11
ALI--MK	UNIV LETHBRIDGE	CANADA	10
HU--BB	HONG KONG BAPTIST UNIV	CHINA	10
LLIBRE--J	UNIV AUTONOMA BARCELONA	SPAIN	10
GREBOGI--C	UNIV SAO PAULO	BRAZIL	9
KIM--SY	KANGWEON NATIONAL UNIV	SOUTH KOREA	9
KURTHS--J	UNIV POTSDAM	GERMANY	9
KUZNETSOV--SP	RUSSIAN ACADEMY OF SCIENCES	RUSSIA	9
LIU--JM	UCLA	USA	9
LIU--ZR	YUNNAN UNIV	CHINA	9
OTT--E	UNIV MARYLAND	USA	9

Of the nineteen most prolific authors listed in Table 2A, six are from China. In fact, eight are from the Far East, four are from Western Europe, one is from Eastern Europe, five are from North America, and one is from South America. Seventeen are from universities, and two are from research institutes.

To determine the trends in this regional mix of prolific authors, the same query was applied to 1991 only. Table 2B lists the most prolific authors for 1991.

TABLE 2B – MOST PROLIFIC AUTHORS - 1991

AUTHOR	INSTITUTION	COUNTRY	#PAPERS
OTT--E	UNIV MARYLAND	USA	13
GRAHAM--R	UNIV ESSEN GESAMTHSCH	GERMANY	12
PARISI--J	UNIV TUBINGEN	GERMANY	9
YORKE--JA	UNIV MARYLAND	USA	9
VAVRIV--DM	AM GORKII STATE UNIVERSITY	UKRAINE	8
SHEPELYANSKY--DL	NOVOSIBIRSK NUCL PHYS INST	SIBERIA	7
GREBOGI--C	UNIV MARYLAND	USA	6
MANDEL--P	UNIV LIBRE BRUXELLES	BELGIUM	6
SCOTT--SK	UNIV LEEDS	ENGLAND	6
STOOP--R	UNIV ZURICH	SWITZERLAND	6
SWINNEY--HL	UNIV TEXAS	USA	6
TEMAM--R	UNIV PARIS	FRANCE	6
ASHOURABDALLA--M	UCLA	USA	5
BADII--R	LAUSANNE UNIV	SWITZERLAND	5
BUCHNER--J	UCLA	USA	5
CASATI--G	UNIV MILAN	ITALY	5
ELNASCHIE--MS	CORNELL UNIV	USA	5
EPSTEIN--IR	BRANDEIS UNIV	USA	5
ERTL--G	MAX PLANCK GESELL	GERMANY	5

The regional mix of authors has some major differences from the 2001 results. Of the nineteen most prolific authors listed in Table 2B, none are from the Far East, eight are from the USA, nine are from Western Europe, and two are from Eastern Europe. Eighteen are from universities, and one is from a research institute.

Only two names were common to both lists, Ott and Grebogi. However, some researchers can have an off year for a number of reasons, so individual comparisons over two years, especially two widely separated years, may not be overly important. More important are country comparisons, and maybe institutional comparisons to some extent. These entities integrate over many individuals, and their performance would be more reflective of national policy. In this regard, the aggregate shift of prolific performers from the NATO countries in 1991 to those of the Far East in 2001 stands out.

4.1.1.2 Clustering Results

Appendix 1 presents three clustering approaches for generating groups of related technical areas. The base data is a square co-occurrence matrix of the highest frequency technical phrases. The two statistical clustering processes listed can also be extrapolated to clustering authors, and other bibliometric quantities. A square co-occurrence matrix of the 253 most prolific authors (each matrix element represents the number of times each author pair is listed on the same paper) was generated, and clusters of related authors were then generated by the two statistical methods: factor matrix and multi-link aggregation.

4.1.1.2.1 Factor Matrix

The co-occurrence matrix was converted to a correlation matrix using the TechOasis software package. Then, the correlation matrix was converted to a factor matrix using the WINSTAT software package. Each matrix element contains the factor loading, a measure of the importance of each author to each factor. The number of factors was unconstrained, but the eigenvalues had a floor of unity. Practically, this means that each factor provides some additional useful information.

Appendix 3A contains the complete factor matrix for all 253 authors. Factor loading values above a threshold were shaded. Each column represents one factor, and the dark vertical bands in each column represent the essential contributors to each factor. The most cohesive factors start from the left column, and proceed to decrease in strength monotonically to the right. Thus, the strongest factor is the first, consisting of the authors ranging from Khan to Ghosh. Additionally, since the factors are not fully orthogonal, some authors can be connected strongly to more than one factor. Therefore, all the authors that represent the core of a factor are not necessarily presented in contiguous form. For example, the initial display of strong contributors to factor 4 is shown near the top: Liu, Davis, and Aida. Further down the column, it is seen that Liu and Chen are strong contributors as well, but they forge an even stronger

link when allied with Tang. Based on name ethnicity alone, intra-country clustering appears to be the dominant form of grouping. This will be examined later with country clustering.

4.1.1.2.2 Multi-Link Aggregation

To obtain a slightly different perspective on groupings, as well as to obtain more detail into sub-groupings within each factor, multi-link aggregation was performed. The co-occurrence matrix was normalized, and clusters of related authors were generated using the multi-link aggregation method of the WINSTAT software package described in Appendix 1.

Appendix 3B contains the full dendogram for the 253 most prolific authors. The ordinate is the 'distance', a measure of the coupling strength between authors, or groups of authors. Smaller 'distance' means stronger coupling. The abcissa is authors, and positioning of an author, or group of authors, along the axis also reflects the relationships among authors or groups.

The authors from Factor 1 of the factor matrix are shown to constitute a cluster (at the bottom of the dendogram). Additionally, the detailed structure within the Factor 1 cluster is evident from the dendogram. Khan and Gupta form a very tightly knit unit; that unit in combination with Sarkar forms a tightly knit unit and, in combination with Ghosh, forms a moderately knit unit.

Table 2C is a co-occurrence matrix of the authors contained in Factor 1.

TABLE 2C - FACTOR 1 AUTHORS CO-OCCURRENCE MATRIX

	KHAN M	GUPTA MR	SARKAR S	GHOSH S
KHAN M	5	5	5	5
GUPTA MR	5	5	5	5
SARKAR S	5	5	6	5
GHOSH S	5	5	5	7

The closeness of the sub-group members depicted schematically on the dendogram is confirmed by the actual numbers of papers. All of Khan's and Gupta's five papers are published with each other and with Sarkar and Ghosh as well. Five out of six of Sarkhar's papers are published with the other three authors, as are five out of seven of Ghosh's papers.

4.1.2 Journals Containing Most Nonlinear Dynamics Papers

There were 1151 different journals represented, with an average of 11.90 papers per journal. The journals containing the most nonlinear dynamics papers (see Table 3A) had more than an order of magnitude more papers than the average.

TABLE 3A – JOURNALS CONTAINING MOST PAPERS - 2001

JOURNAL	# PAPERS
PHYS. REV. E	489
PHYS. REV. LETT.	175
INT. J. BIFURCATION CHAOS	164
PHYS. LETT. A	125
PHYSICA D	113
CHAOS SOLITONS FRACTALS	104
NONLINEAR ANAL.-THEORY METHODS APPL.	100
IEEE TRANS. CIRCUITS SYST. I-FUNDAM. THEOR. APPL.	92
PHYSICA A	85
PHYS. REV. B	84
J. PHYS. A-MATH. GEN.	73
PHYS. REV. A	72
J. FLUID MECH.	56
ACTA PHYS. SIN.	52
PHYS. PLASMAS	51
PHYS. REV. D	51
J. CHEM. PHYS.	48
J. SOUND VIBR.	45
PHYS. SCR.	45
ASTROPHYS. J.	45

The majority of the journals are physics, with the remainder divided between mathematics and electronics. Phys Rev E is the Physical Review journal assigned to chaos, while Phys Rev letters receives important papers for rapid publishing. Many (not all) of the other journals do not focus on nonlinear topics, but include papers in their specialties that also involve nonlinear aspects.

To determine the trends in journals containing the most nonlinear dynamics papers, the results from 1991 are examined. Table 3B contains the top twenty journals.

TABLE 3B – JOURNALS CONTAINING MOST PAPERS - 1991

JOURNAL	# PAPERS
PHYS. REV. A	176
PHYS. LETT. A	98
PHYSICA D	97
PHYS. REV. LETT.	77
J. FLUID MECH.	49
J. CHEM. PHYS.	48

EUROPHYS. LETT.	37
PHYS. REV. B-CONDENS MATTER	37
NONLINEARITY	37
J. PHYS. A-MATH. GEN.	32
GEOPHYS. RES. LETT.	28
J. STAT. PHYS.	28
ASTROPHYS. J.	24
EUR. J. MECH. B-FLUIDS	24
OPT. COMMUN.	23
NONLINEAR ANAL.-THEORY METHODS APPL.	20
PHYS. REV. D	19
LECT. NOTES MATH.	19
INT. J. NON-LINEAR MECH.	18
J. PHYS. CHEM.	17

While the most prolific authors could be expected to change over a decade, for a number of reasons, the most prolific journals should be more stable. Comparison of Tables 3A and 3B shows this to be true. Of the nineteen most prolific journals, eleven are in common. For 2001, two journals were added devoted solely to chaos and closely related topics (CHAOS SOLITONS FRACTALS, INTERNATIONAL JOURNAL OF BIFURCATION AND CHAOS). Perhaps the largest change is the drop of Physical Review A from first in 1991 to twelfth in 2001, and the appearance of Physical Review E as first in 2001. Phys Rev E was split from Phys Rev A during the past decade, and received the Physical Review assignment for papers in chaos.

4.1.3 Institutions Producing Most Nonlinear Dynamics Papers

A similar process was used to develop a frequency count of institutional address appearances. It should be noted that many different organizational components may be included under the single organizational heading (e.g., Harvard Univ could include the Chemistry Department, Biology Department, Physics Department, etc.). Identifying the higher level institutions is instrumental for these DT studies. Once they have been identified through bibliometric analysis, subsequent measures may be taken (if desired) to identify particular departments within an institution.

TABLE 4A – PROLIFIC INSTITUTIONS – 2001

INSTITUTION	COUNTRY	# PAPERS
RUSSIAN ACAD SCI	RUSSIA	165
CHINESE ACAD SCI	CHINA	72
UNIV TOKYO	JAPAN	68
UNIV CALIF SAN DIEGO	USA	67
UNIV MARYLAND	USA	61
UNIV CALIF BERKELEY	USA	53
ARIZONA STATE UNIV	USA	48

UNIV CALIF LOS ANGELES	USA	47
FREE UNIV BRUSSELS	BELGIUM	47
CORNELL UNIV	USA	43
UNIV TEXAS	USA	43
UNIV HOUSTON	USA	41
UNIV ILLINOIS	USA	41
GEORGIA INST TECHNOL	USA	40
PRINCETON UNIV	USA	40
INDIAN INST TECHNOL	INDIA	39
MIT	USA	38
CNRS	FRANCE	37
IST NAZL FIS NUCL	ITALY	36
MAX PLANCK INST PHYS KOMPLEXER SYST	GERMANY	36
TECHNION ISRAEL INST TECHNOL	ISRAEL	36
BEIJING NORMAL UNIV	CHINA	36
MOSCOW MV LOMONOSOV STATE UNIV	RUSSIA	36
NORTHWESTERN UNIV	USA	36
UNIV SAO PAULO	BRAZIL	34
TECH UNIV DENMARK	DENMARK	34
UNIV WASHINGTON	USA	34
UNIV PARIS 06	FRANCE	33
CITY UNIV HONG KONG	CHINA	33
UNIV CAMBRIDGE	ENGLAND	33

Of the thirty most prolific institutions, fourteen are from the USA, seven are from Western Europe, five are from Asia, two are from Eastern Europe, one is from Latin America, and one is from the Middle East. Twenty-five are universities, and the remaining institutions are research institutes. The most prolific institutions for nonlinear dynamics papers correlate well with institutions that have Centers for nonlinear dynamics.

To determine the trends in institutions containing the most nonlinear dynamics papers, the results from 1991 were examined. Table 4B contains the top thirty institutions.

TABLE 4B – PROLIFIC INSTITUTIONS – 1991

INSTITUTION	COUNTRY	# PAPERS
ACAD SCI USSR	USSR	49
UNIV TEXAS	USA	35
MIT	USA	33
UNIV MARYLAND	USA	31
UNIV CAMBRIDGE	ENGLAND	29
USN	USA	29
UNIV CALIF LOS ANGELES	USA	28
CORNELL UNIV	USA	27
UNIV CALIF SAN DIEGO	USA	26

CALTECH	USA	25
ACAD SCI UKSSR	USSR	25
UNIV ILLINOIS	USA	25
UNIV CALIF LOS ALAMOS SCI LAB	USA	24
UNIV ARIZONA	USA	23
UNIV TORONTO	CANADA	22
UNIV CALIF BERKELEY	USA	22
UNIV MINNESOTA	USA	21
UNIV PARIS 11	FRANCE	21
NASA	USA	21
NORTHWESTERN UNIV	USA	20
UNIV LEEDS	ENGLAND	20
GEORGIA INST TECHNOL	USA	19
UNIV ESSEN GESAMTHSCH	GERMANY	19
UNIV HOUSTON	USA	19
UNIV TOKYO	JAPAN	18
MV LOMONOSOV STATE UNIV	USSR	18
UNIV PARIS 06	FRANCE	18
PRINCETON UNIV	USA	17
BROWN UNIV	USA	16
UNIV COLORADO	USA	16

Of the thirty most prolific institutions in 1991, twenty are from the USA, five are from Western Europe, three are from Eastern Europe, one is from Asia, and one is from Canada. The major shift is substitution of Asian institutions for USA institutions. In addition, twenty-five institutions are universities, and five are research institutes.

There are at least five factors that underlay the quality and quantity of nonlinear dynamics research. First, nonlinear dynamics is on the cutting edge of physics research, and has applicability to many different S&T disciplines. It is a prime research area for an institution's academic expansion.

Second, advances in nonlinear dynamics requires people who are intelligent and well-trained in physics and mathematics. Asian countries have large populations, and large numbers of researchers, well trained in physics, mathematics, and other fundamental disciplines. They tend to score well in international scientific education competitions. They have the educational foundations for becoming major contributors.

Third, much of nonlinear dynamics requires the extensive use of computers, to perform and display results of theoretical computations, and support analysis of experimental data. The growth of affordable personal computers, mainly in the decade of the 90s , has allowed poor third-world countries to acquire modern computational facilities, and compete as almost equals in this area.

Fourth, there is a strong theoretical component, that requires substantial intellect and minimal funding. This provides poorer countries with a large supply of well-educated professionals the opportunity to gain high visibility in theoretical studies of nonlinear dynamics.

Fifth, there is a strong data analysis component, with three aspects to the data analysis: 1) the ease in obtaining the data; 2) the ability to analyze the data; 3) the tools needed to support the analysis. Item 2) requires well-trained professionals, and the proliferation of such people in Asian countries was addressed previously. Item 3) involves modern computers, and the recent proliferation of these facilities in Asian countries was also addressed previously. Item 1) depends on the data source. For data that requires expensive laboratory or field or flight tests to acquire, the poorer countries are at a distinct dis-advantage relative to the developed countries. For example, in the China/ USA comparison presented later, it is shown that China has very little effort in disciplines such as space phenomena analysis or controlled fusion plasma analysis. This is undoubtedly related to the high costs of acquiring data in these areas, and China's lack of a substantial experimental effort in these areas. However, there is much data that can be analyzed with the techniques of nonlinear dynamics that does not require expensive facilities, and the less affluent Asian countries can focus substantial efforts in these areas.

4.1.4 Countries Producing Most Nonlinear Dynamics Papers

There are 78 different countries listed in the results for 2001. The country bibliometric results are summarized in Table 5A and shown graphically in Figure 1. The dominance of a handful of countries is clearly evident.

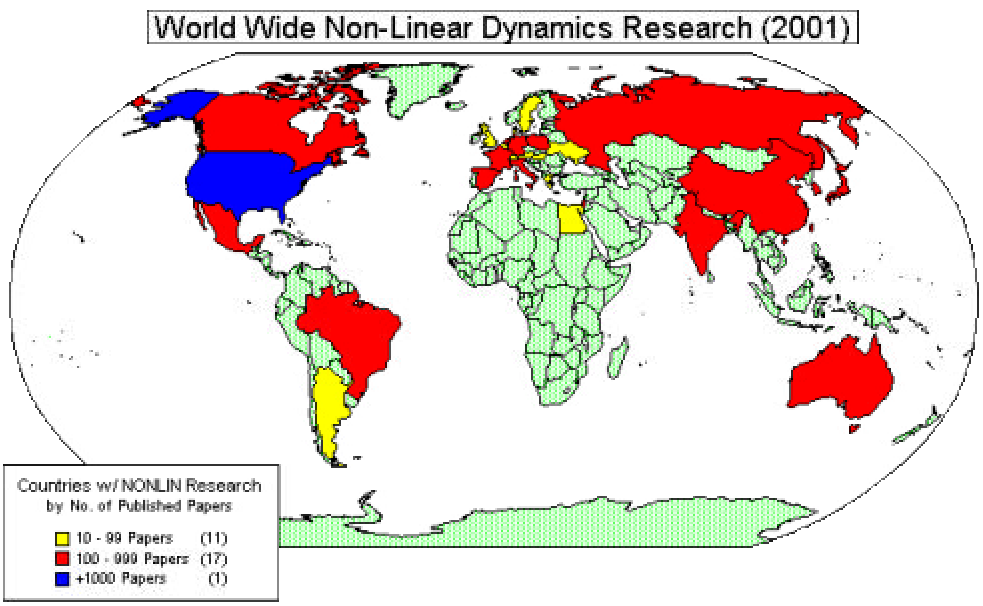
TABLE 5A – PROLIFIC COUNTRIES - 2001

COUNTRY	# PAPERS
USA	1797
PEOPLES R CHINA	588
GERMANY	585
JAPAN	470
FRANCE	426
ENGLAND	415
RUSSIA	394
ITALY	338
SPAIN	260
CANADA	242
BRAZIL	173
INDIA	157

NETHERLANDS	141
ISRAEL	127
POLAND	123
AUSTRALIA	118
TAIWAN	110
SOUTH KOREA	109
MEXICO	101
BELGIUM	99
UKRAINE	79
GREECE	74
SWEDEN	71
ARGENTINA	70
DENMARK	60
SCOTLAND	55
SWITZERLAND	53
AUSTRIA	47
HUNGARY	47
EGYPT	35

There appear to be two dominant groupings. The first group is the USA. It has as many papers as the members of the second group, People's Republic of China, Germany, and Japan.

FIGURE 1 – COUNTRIES WITH THE MOST NONLINEAR DYNAMICS PAPERS – 2001


World Wide Non-Linear Dynamics Research (2001)
Countries w/ NONLIN Research
by No. of Published Papers
10 - 99 Papers (11)
100 - 999 Papers (17)
+1000 Papers (1)

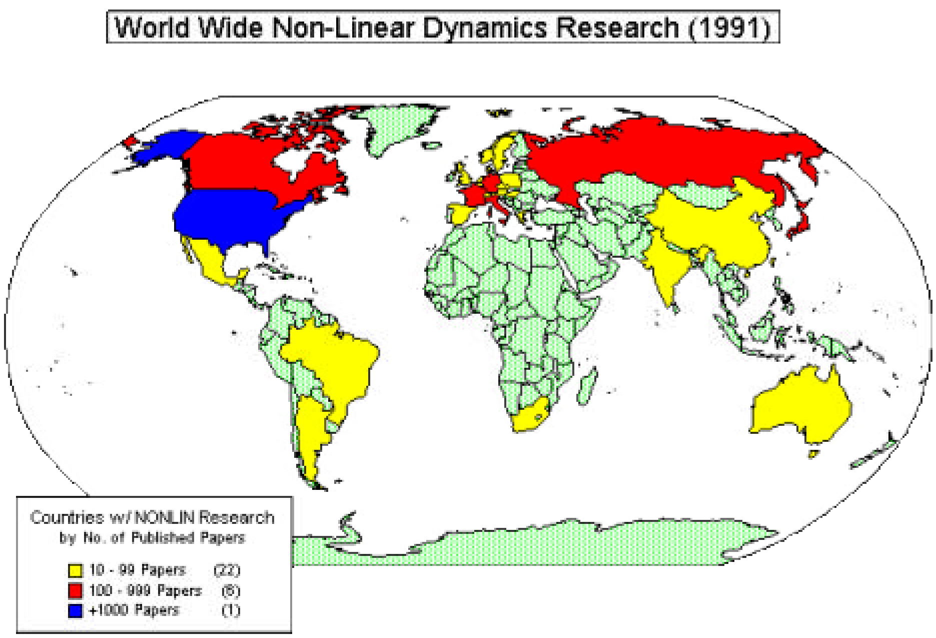
To determine the trends in countries containing the most nonlinear dynamics papers, the results from 1991 were examined. Table 5B summarizes results from the top twenty countries, and Figure 2 displays these results graphically.

TABLE 5B – PROLIFIC COUNTRIES - 1991

COUNTRY	# PAPERS
USA	1031
GERMANY	247
USSR	207
ENGLAND	162
FRANCE	158
JAPAN	154
CANADA	118
ITALY	117
INDIA	65
POLAND	65
PEOPLES R CHINA	63
ISRAEL	52
AUSTRALIA	43
NETHERLANDS	43
SWITZERLAND	40
SPAIN	38
BELGIUM	27
BRAZIL	26
GREECE	25
DENMARK	22
HUNGARY	22

SCOTLAND	22
TAIWAN	22
CZECHOSLOVAKIA	17
SWEDEN	16
AUSTRIA	13
ARGENTINA	11
SOUTH AFRICA	11
MEXICO	10
NORWAY	10

FIGURE 2 – COUNTRIES WITH THE MOST NONLINEAR DYNAMICS PAPERS – 1991



The major shift is the increased ranking of People's Republic of China from 11th in 1991 to 2nd in 2001, and the concomitant increase in numbers of papers from 63 to 584. To place China's increase in Nonlinear Dynamics papers in perspective, it is compared to China's overall increase in SCI papers from 1991 to 2001. In 1991, China had 8174 entries in the SCI, and in 2001, China had 36765 entries in the SCI. Thus, while China's papers in Nonlinear Dynamics in the SCI increased by a factor of ~9.25 from 1991 to 2001, China's overall increase in SCI papers from 1991 to 2001 was a factor of ~4.5. Thus, China's Nonlinear Dynamics papers outpaced its average growth of SCI papers by a factor of ~ 2.

Appendix 4 contains a co-occurrence matrix of the top 15 countries. In terms of absolute numbers of co-authored papers, the USA major partners are Germany, China, France, Canada, and England. Interestingly, the USA is China's dominant major partner, having four times the number of co-authored papers with China (72) as China's next larger partner, Canada (18). Overall, countries in similar geographical regions tend to co-publish substantially, the US being a moderate exception.

4.2 Citation Statistics on Authors, Papers, and Journals

The second group of metrics presented is counts of citations to papers published by different entities. While citations are ordinarily used as impact or quality metrics (14), much caution needs to be exercised in their frequency count interpretation, since there are numerous reasons why authors cite or do not cite particular papers (15, 16).

The citations in all the retrieved SCI papers were aggregated, the authors, specific papers, years, journals, and countries cited most frequently were identified, and were presented in order of decreasing frequency. A small percentage of any of these categories received large numbers of citations. From the citation year results, the most recent papers tended to be the most highly cited. This reflected rapidly evolving fields of research.

4.2.1 Most Cited Authors

The most highly cited authors are listed in Table 6.

TABLE 6 – MOST CITED AUTHORS
(cited by other papers in this database only)

AUTHOR	INSTITUTION	COUNTRY	# CITES
OTT E	UNIV MARYLAND	USA	399
GRASSBERGER P	KFA JULICH GMBH	GERMANY	329
PECORA LM	USN	USA	323
GUCKENHEIMER J	CORNELL	USA	305
NAYFEH AH	VPI	USA	296

KANEKO K	UNIV TOKYO	JAPAN	247
BERRY MV	UNIV BRISTOL	ENGLAND	235
ARNOLD VI	RUSSIAN ACADEMY OF SCIENCE	RUSSIA	230
TAKENS F	UNIV GRONINGEN	NETHERLANDS	212
GASPARD P	FREE UNIV BRUSSELS	BELGIUM	199
GUTZWILLER MC	IBM	USA	194
THEILER J	LOS ALAMOS NATIONAL LAB	USA	194
ABARBANEL HDI	UNIV CAL SAN DIEGO	USA	193
GREBOGI C	UNIV SAO PAULO	BRAZIL	192
LAI YC	ARIZONA STATE	USA	187
ECKMANN JP	UNIV GENEVA	SWITZERLAND	185
LORENZ EN	MIT	USA	174
PIKOVSKY AS	UNIV POTSDAM	GERMANY	172
PRESS WH	HARVARD UNIV	USA	163
CASATI G	UNIV INSUBRIA	ITALY	163

Of the twenty most cited authors, ten are from the USA, seven from Western Europe, one from Russia, one from Japan, and one from Latin America. This is a far different distribution from the most prolific authors of 2001, where eight of nineteen were from the Far East. This distribution of most cited authors more closely resembles the distribution of most prolific authors from 1991, where none were from the Far East.

There are a number of potential reasons for this difference between most prolific and cited authors in 2001. The most prolific may not be the highest quality, or many of the most prolific authors could be relatively recent, and insufficient time has elapsed for their citations to accumulate. In another three or four years, when the papers from present-day authors have accumulated sufficient citations, firmer conclusions about quality can be drawn.

The lists of nineteen most prolific authors from 2001 and twenty most highly cited authors only had five names in common (OTT, NAYFEH, GASPARD, GREBOGI, LAI). This phenomenon of minimal intersection has been observed in all other text mining studies performed by the first author.

Fifteen of the authors' institutions are universities, four are government-sponsored research laboratories, and one is a private company.

The citation data for authors and journals represents citations generated only by the specific records extracted from the SCI database for this study. It does not represent all the citations received by the references in those records; these references in the database records could have been cited additionally by papers in other technical disciplines.

4.2.2 Most Cited Papers

The most highly cited documents are listed in Table 7.

TABLE 7 – MOST CITED DOCUMENTS
(total citations listed in SCI)

AUTHOR NAME	YEAR	JOURNAL	VOLUME/ PAGE	# SCI CITES
PECORA LM	1990	PHYS REV LETT	V64,P821	938
(SYNCHRONIZATION IN CHAOTIC SYSTEMS)				
GUCKENHEIMER J	1983	NONLINEAR OSCILLATIONS		
(MATHEMATICAL STUDIES OF BIFURCATIONS)				
OTT E	1990	PHYS REV LETT	V64,P1196	1274
(CONTROLLING CHAOS)				
LORENZ EN	1963	J ATMOS SCI	V20,P130	2971
(DETERMINISTIC NONPERIODIC FLOW)				
CROSS MC	1993	REV MOD PHYS	V65,P851	1500
(PATTERN-FORMATION OUTSIDE OF EQUILIBRIUM)				
WOLF A	1985	PHYSICA D	V16,P285	1566
(DETERMINING LYAPUNOV EXPONENTS FROM A TIME-SERIES; INTRODUCED CHAOS)				
TAKENS F	1981	LECT NOTES MATH	V898,P366	
(MATHEMATICAL PAPER ON ANALYSIS OF CHAOTIC TIME SERIES)				
OTT E	1993	CHAOS DYNAMICAL SYST		
(CHAOS CONTROL THEORY)				
GRASSBERGER P	1983	PHYSICA D	V9,P189	1567
(MEASURING THE STRANGENESS (FRACTAL GEOMETRY) OF STRANGE ATTRACTORS)				
GUTZWILLER MC	1990	CHAOS CLASSICAL QUAN		
(QUANTUM IDEAS ON CHAOS)				
ROSENBLUM MG	1996	PHYS REV LETT	V76,P1804	241
(PHASE SYNCHRONIZATION OF CHAOTIC OSCILLATORS)				
GRASSBERGER P	1983	PHYS REV LETT	V50,P345	1369
(CHARACTERIZATION OF STRANGE ATTRACTORS IN AN OSCILLATOR'S PHASE SPACE)				
ECKMANN JP	1985	REV MOD PHYS	V57,P617	1557
(ERGODIC-THEORY OF CHAOS AND STRANGE ATTRACTORS)				
THEILER J	1992	PHYSICA D	V58,P77	568
(SURROGATE DATA TESTING FOR NONLINEARITY IN TIME-SERIES)				
NAYFEH AH	1979	NONLINEAR OSCILLATIONS		

(TEXTBOOK ON NONLINEAR MECHANICS)			
FUJISAKA H	1983 PROG THEOR PHYS	V69,P32	294
(STABILITY THEORY OF SYNCHRONOUS MOTION IN COUPLED-OSCILLATOR SYSTEM)			
WIGGINS S	1990 INTRO APPL NONLINEAR		
(APPLIED NONLINEAR DYNAMICAL SYSTEMS AND CHAOS)			
RULKOV NF	1995 PHYS REV E	V51,P980	213
(SYNCHRONIZATION OF CHAOS IN DIRECTIONALLY COUPLED CHAOTIC SYSTEMS)			
PYRAGAS K	1992 PHYS LETT A	V170,P421	512
(CONTINUOUS CONTROL OF CHAOS BY SELF-CONTROLLING FEEDBACK)			
LICHTENBERG AJ	1992 REGULAR CHAOTIC DYNA		
(CHAOTIC MOTION IN NONLINEAR DYNAMICAL SYSTEMS)			

The theme of each paper is shown in italics on the line after the paper listing. The order of paper listings is by number of citations by other papers in the extracted database analyzed. The total number of citations from the SCI paper listing, a more accurate measure of total impact, is shown in the last column on the right.

Physical Review Letters contains the most papers by far, four out of the twenty listed. Most of the journals are fundamental science journals, and most of the topics have a fundamental science theme. The majority of the papers are from the 1990s, with seven from the 1980s, one from the 1970s, and one extremely highly cited paper being from 1963. This reflects a dynamic research field, with seminal works being performed in the recent past.

Eight of the papers address issues related to chaos, with the dominant themes being conditions for determining chaos, and properties of strange attractors Four of the papers address issues related to synchronization, with the focus on coupled chaotic oscillators.. Three of the papers address issues related to control, emphasizing self-controlling feedback. One paper addresses stability-related issues, focusing on bifurcations, and one paper focuses on quantum chaos. There are three nonlinear dynamics books in the top twenty cited documents.

Thus, the major intellectual emphasis of cutting edge Nonlinear Dynamics research, as evidenced by the most cited papers, is well aligned with the intellectual heritage and performance emphasis, as will be evidenced by the clustering approaches.

4.2.3. Most Cited Journals

The most highly cited journals are listed in Table 8.

TABLE 8 – MOST CITED JOURNALS
(cited by other papers in this database only)

JOURNAL	TIMES CITED
PHYS REV LETT	10786
PHYS REV E	5310
PHYS REV A	3603
PHYSICA D	3579
PHYS LETT A	2308
J CHEM PHYS	2138
J FLUID MECH	2002
PHYS REV B	1969
NATURE	1911
ASTROPHYS J	1367
INT J BIFURCAT CHAOS	1279
SCIENCE	1256
PHYS REV D	1215
J PHYS A-MATH GEN	1073
PHYS FLUIDS	907
J ATMOS SCI	871
REV MOD PHYS	864
PHYS REP	813
J STAT PHYS	790
CHAOS	777

The first two groups of cited journals clearly stand out. PHYS REV LETT received almost as many cites as the three journals in the next group (PHYS REV E, PHYS REV A, PHYSICA D), or even the five journals in the following group (PHYS LETT A, J CHEM PHYS, J FLUID MECH, PHYS REV B, NATURE). PHYS REV LETT emphasizes rapid publication of ‘hot’ topics, and would therefore tend to establish primacy in an emerging field. Since one aspect of citations is identifying the original literature of a new topic, a credible journal with these characteristics would tend to receive large numbers of citations.

Unlike the relatively disjoint relationship between most prolific authors in 2001 and most cited authors, the relationship between most prolific journals in 2001 and most cited journals was much closer. Nine of the ten most highly cited journals were also on the list of twenty most prolific journals in 2001. The more applied journals on the most prolific list for 2001 are replaced by the more fundamental journals on the most cited list.

The authors end this bibliometrics section by recommending that the reader interested in researching the topical field of interest would be well-advised to, first, obtain the highly-cited papers listed and, second, peruse those sources that are highly cited and/or contain large numbers of recently published papers.

4.3 Database Tomography Results

There are two major analytic methods used in this section to generate taxonomies of the SCI databases: non-statistical clustering, based on phrase frequency analysis, and statistical clustering, based on phrase proximity analysis. They are described in Appendix 1.

4.3.1. Taxonomies

4.3.1.1 Non-Statistical Clustering

4.3.1.1.1. Keyword Taxonomy

All the Keywords from the extracted SCI records, and their associated frequencies of occurrence (with a threshold frequency of nine), were tabulated, and then grouped into categories by visual inspection. The phrases were of two types: applications-related and phenomena or tech base-related. While the application sub-categories were relatively independent, there was substantial overlap among some of the tech base categories. The detailed taxonomy results are presented in Appendix 5. Within each sub-category, thrust areas are presented in approximate frequency appearance order. These results are displayed in Table 9, and summarized now.

TABLE 9 – KEYWORD TAXONOMY

SUB-CATEGORIES	SUB-CAT FREQ SUMS	CATEGORIES	CAT FREQ SUMS
FLUID FLOW	845	APPLICATIONS	845
OPTICS	273	APPLICATIONS	1118
BRAIN	277	APPLICATIONS	1395
ENVIRONMENT	131	APPLICATIONS	1526
COSMOLOGY	147	APPLICATIONS	1673
MATERIALS	88	APPLICATIONS	1761
CHEMISTRY	82	APPLICATIONS	1843
PLASMA	76	APPLICATIONS	1919
SPATIAL BOUNDARY	56	BOUNDARIES	56
INITIALIZATION	46	BOUNDARIES	102
SIGNALS	667	COMMUNICATION	667
CIRCUITS	102	COMMUNICATION	769
CONTROL	216	CONTROL	216
SYNCHRONIZATION	397	COUPLING	397
RESONANCE	149	COUPLING	546
OSCILLATIONS	693	CYCLING	693
PERIODICITY	250	CYCLING	943
WAVES	234	CYCLING	1177

EXPERIMENT	193	EXPERIMENT	193
GEOMETRY	146	GEOMETRY	146
MODEL AND SIM	1012	MODEL AND SIM	1012
EVOLUTION	1870	MOTION	1870
CHAOS	1056	MOTION	2926
QUANTUM	520	SCALING	520
DIMENSIONALITY	205	SCALING	725
LOCALIZATION	88	SCALING	813
SCALING	38	SCALING	851
STABILITY	1378	STABILITY	1378
MAPS	115	STABILITY	1493
NONLINEAR	222	STRUCTURES	222
STATES	298	STRUCTURES	520
THEORY	215	THEORY	215
ENTROPY	284	THERMODYNAMICS	284
NOISE	144	THERMODYNAMICS	428
STATISTICS	142	THERMODYNAMICS	570
DISSIPATION	78	THERMODYNAMICS	648
THERMODYNAMICS	59	THERMODYNAMICS	707
CONSERVATION	42	THERMODYNAMICS	749

There are eight distinct applications categories, with four levels of stratification based on phrase frequency summations. Fluid Flow is the dominant stratification level, with the main emphasis being turbulence, convective transport, and diffusion. The second stratification level consists of Optics and Brain. The Optics emphases are lasers and associated nonlinear phenomena, while the Brain emphases are neural networks and analyses of broader neural system signals. The third stratification level consists of Environment and Cosmology. The Environment emphases are earthquakes and storms, while the Cosmology emphases center around evolution of the universe. The fourth stratification level consists of Materials, Chemistry, and Plasma (mostly fusion physics based). The Materials emphasis are split between solid mechanics/ structures issues and electronic properties/ applications issues.

There are fourteen tech base categories, also with four main stratification levels based on phrase frequency summations. The dominant level is Motion, consisting of the sub-categories Evolution and Chaos. Evolution emphases are attractors and nonlinear dynamics. The second level consists of Stability, comprised of the sub-categories Stability and Maps. Stability emphases are bifurcations and the transitions to instability, while Maps emphasizes Poincare's surface intersections. The third level comprises Cycling and Modeling and Simulation, with Cycling further categorized into Oscillations, Periodicity, and Waves. Under Oscillations, nonlinear, chaotic, and coupled oscillators are emphasized, as well as limit cycles; under Periodicity, the focus is periodic orbits; and under Waves, the emphasis is traveling and solitary waves.

The fourth stratification level consists of Communication, Scaling, Thermodynamics, and Coupling. Communication comprises Signals and Circuits; Scaling comprises Quantum, Dimensionality, Localization, and Scaling; Thermodynamics comprises Entropy, Noise, Statistics, Dissipation, Thermodynamics, and Conservation; and Coupling comprises Synchronization and Resonance. .Under Signals, time series analysis and the associated intermittency are emphasized; under Quantum, small particle motions and interactions are emphasized; under Dimensionality, different measures of fractal dimensions of strange attractors are emphasized; under Entropy, patterns and pattern formation are emphasized; under Noise, brownian motion is emphasized; under Dissipation, hysteresis and friction are emphasized; and under Resonance, stochastic resonance is emphasized.

4.3.1.1.2 Abstract Taxonomy

A taxonomy of nonlinear dynamics applications and phenomena was developed through visual inspection of the TextDicer Abstract phrase frequencies. The developed taxonomy was subsequently used to approximate global levels of emphasis (GLE). This type of analysis would help identify adequately and inadequately supported system and subsystem tech base areas. It could also differentiate the developed and developing technology components of a particular system.

The manual Abstract taxonomy was developed using two different approaches. The first approach used the marginal utility algorithm described in the information retrieval section. A list of Abstract phrases was generated by TextDicer, and high technical content phrases were selected. For each phrase selected, the records in which the phrase appeared was tagged. For each phrase selected, only those records that were previously untagged ('new' records) were counted for phrase frequency summation purposes.

This type of phrase frequency accounting had three effects. First, since Abstracts were counted, and only counted once, any type of multiple counting was eliminated. Second, all Abstracts had the same weighting. Any skewing due to Abstract length differences was eliminated. Third, only one theme per Abstract was counted. Thus, if an Abstract described multiple phenomena, only one was counted. Also, if an application and phenomena were described, only one or the other would be represented by the phrase selected. While the first two effects were viewed as positive normalizing effects, the third effect was viewed as negative. Much information was lost from the third effect, because of the counting of one phrase only per Abstract. In addition, the order in which the phrases were selected affected the frequency sums. The generic phenomena tended to be represented in the higher frequency Keywords, whereas the applications tended to be represented in the lower frequency Keywords. Since the higher technical content longer keywords were of interest because of the detail provided, selection started from the lower frequency Keywords and progressed to the higher frequency keywords.

The second taxonomy development approach used absolute Abstract phrase frequencies from TextDicer. Since the present incarnation of TextDicer allows multiple counting of nested phrases (e.g., METAL and METAL MATRIX are both counted for frequency summation purposes, and therefore METAL is counted twice), corrections are required to eliminate multiple counting. Thus, in the second approach, categories were generated by visual inspection, and phrases were assigned manually. The frequencies were corrected to counter the effects of nesting, and then the frequencies were summed for each category.

Table 10 contains both the manual Abstract taxonomy generated using the marginal utility algorithm and the manual Abstract taxonomy generated without the marginal utility algorithm. Appendix 6A contains the Abstract phrases (marginal utility) and their allocation to categories, and Appendix 6B contains the Abstract phrases (non-marginal utility) and their allocation to categories.

TABLE 10 – MANUAL ABSTRACT TAXONOMY

SUB-CATEGORY	MARG UTIL SUB-CAT FREQ SUMS	NON-MARG UTIL SUB-CAT FREQ SUMS	CATEGORY	MARG UTIL CAT FREQ SUMS	NON-MARG UTIL CAT FREQ SUMS
FLUID FLOW	279	1025	APPLICATIONS		
CHEMISTRY	161	359	APPLICATIONS		
COSMOLOGY	153	353	APPLICATIONS		
BRAIN	114	606	APPLICATIONS		
MATERIALS	99	217	APPLICATIONS		
ENVIRONMENT	91	404	APPLICATIONS		
LASER	89	348	APPLICATIONS		
MEDICAL	81	204	APPLICATIONS		
GEOLOGY	76	274	APPLICATIONS		
BIOLOGY	62	246	APPLICATIONS		
SOLID STATE	58	264	APPLICATIONS		
OPTICAL	49	506	APPLICATIONS		
OCEAN	42	167	APPLICATIONS		
PLASMA	22	174	APPLICATIONS		
POPULATION	15	33	APPLICATIONS	1391	5180
TIME BOUNDARY	60	300	BOUNDARIES		
SPATIAL BOUNDARY	59	314	BOUNDARIES	119	614
SIGNALS	167	1081	COMMUNICATION		

CIRCUITS	46	220	COMMUNICATION		
COMMUNICATION	18	136	COMMUNICATION		
CODE	16	61	COMMUNICATION	247	1530
CONTROL	240	1361	CONTROL	240	1361
SYNCHRONICITY	114	591	COUPLING		
COUPLING	113	319	COUPLING		
RESONANCE	63	465	COUPLING	290	1375
OSCILLATIONS	247	2106	CYCLING		
PERIODICITY	176	919	CYCLING		
WAVE	151	440	CYCLING	574	3465
EXPERIMENTS	157	1073	EXPERIMENT	157	1073
GEOMETRY	83	580	GEOMETRY	83	580
MODEL AND SIM	434	1931	MODEL AND SIM	434	1931
EVOLUTION	205	1218	MOTION		
CHAOS	196	554	MOTION		
ATTRACTORS	104	799	MOTION	505	2571
QUANTUM	273	1210	SCALING		
DIMENSIONALITY	159	491	SCALING		
SCALING	130	739	SCALING		
LOCALIZATION	36	122	SCALING	598	2562
STABILITY	523	3199	STABILITY		
MAPS	152	655	STABILITY	675	3854
NONLINEAR	130	678	STRUCTURES		
STATES	98	422	STRUCTURES	228	1100
THEORY	143	285	THEORY	143	285
NOISE	102	416	THERMODYNAMICS		
STATISTICS	81	154	THERMODYNAMICS		
ENTROPY	78	256	THERMODYNAMICS		
DISSIPATION	39	303	THERMODYNAMICS		
THERMODYNAMICS	23	118	THERMODYNAMICS	323	1247

Both approaches produce the same categories, although the balance among categories differs. Overall, the ratio (.3) of Applications phrase frequencies (1391) to Phenomena phrase frequencies (4616) for the marginal utility approach is substantially higher than the ratio (.16) of Applications phrase frequencies (5180) to Phenomena phrase frequencies (28728) for the non-marginal utility approach. The query terms were all phenomena-related, and one would expect the Abstract terms to be predominately phenomena-related. Any application terms that arise in the Abstracts are secondary, and are of substantially lower frequency than the phenomena-related terms. Since the marginal utility approach started at the low frequency part of the spectrum in order to extract the more detailed technical phrases, it encountered a greater fraction of applications terms than had it started at the high frequency end. Since the marginal utility approach tags each record once, tagging a record with a low frequency application term would eliminate any high frequency phenomena-related term being counted.

Relative to the Keyword taxonomy, the Abstract taxonomies have two additional categories: Biology and Medical. While biological and medical terms can be found in the list of Keywords, they occur with a frequency lower than that used for cutoff. The reasons for this are unclear. In the Abstract phrase taxonomies, Biological and Medical are not the lowest frequency applications, and if the Keywords correlated with the Abstract phrases, one would expect Biology and Medicine to appear as Keyword taxonomy categories. It could be that: 1) the biomedical community uses a greater fraction of nonlinear dynamics phenomenological terms as Keywords than other application communities; 2) there is less agreement on medical terminology relative to other communities, and a greater variety of low frequency terms are used; or 3), a broader variety of medical sub-areas are being investigated with nonlinear dynamics than some of the other applications areas.

In addition, some new categories were generated for the Abstract taxonomies by fissioning categories in the Keywords taxonomy. For example, Optics in the Keywords taxonomy was split into Optics and Lasers for the Abstracts taxonomies, due to the substantially greater amount of Abstract phrase detail, but it is fundamentally the same category.

Now, the emphasis areas of the Abstract phrase categories will be summarized. Because the single Abstract theme focus of the marginal utility approach is too constraining for purposes of category emphasis estimation, only the non-marginal utility approach will be analyzed.

Applications can be stratified into four main levels, based on summation of phrase frequencies as figure-of-merit. The dominant level consists of Fluid Flow (1025) and Optics (854), the latter including both Optical (506) and Laser (348). Fluid Flow emphasizes turbulence, vorticity, and convection; Optics emphasizes lasers and beams (generically electromagnetic beams, but usually laser or light beams).

The second level consists of Brain (606). Brain emphasizes neuron firings, EEG, epilepsy, and cortex.

The third level consists of Chemistry (359), Cosmology (353), Environment (404), and Material (481), the latter including both Materials (217) and Solid State (264). Chemistry emphasizes reaction and diffusion rates, combustion, catalysis, and Belousov-Zhabotinsky reaction; Cosmology emphasizes galaxies, black holes, and planets; Environment emphasizes atmosphere, weather (wind, climate, storms, rainfall), and ecology; Material emphasizes polymers, viscoelasticity, crystals, semiconductors, diodes, and tunneling.

The fourth major level consists of Medical (204), Geology (274), and Biology (246), Medical emphasizes cardiovascular problems (cardiovascular, blood pressure, fibrillation, heart rate, ventricular, pacemaker), and infectious disease (infection, virus).

Geology emphasizes seismic events (earthquake, ground motion, landslide, seismic, volcanic), and Biology emphasizes genetics, DNA, and circadian rhythms.

Phenomena can be stratified into three main levels, based on summation of phrase frequencies as figure-of-merit. The dominant level consists of Stability (3854) and Cycling (3465). The Stability category can be divided into a Stability sub-category (3199) and a Maps sub-category (655). The Cycling category can be divided into an Oscillations sub-category (2106), a Periodicity sub-category (919), and a Wave sub-category (440).

Within the Stability category, the Stability sub-category emphasizes Hopf, pitchfork, period-doubling, global, saddle-node, homoclinic, local, transcritical, blowout, primary, and subcritical bifurcations, and bifurcation points/ diagrams/ curves/ structure/ control/ set/ buckling/ mechanism, stability and instability [LINEAR AND NONLINEAR STABILITY ANALYSIS, STABLE AND UNSTABLE PERIODIC ORBITS, ASYMPTOTIC STABILITY, ONSET OF INSTABILITY, UNSTABLE FIXED POINT(S), STABLE LIMIT CYCLE(S), UNSTABLE PERIODIC SOLUTIONS, CONDITIONS OF STABILITY, LINEAR STABILITY THEORY], Lyapunov criteria, and critical and equilibrium points; the Maps sub-category emphasizes Poincare, logistic, Henon, return, standard, circle, invertable and non-invertable, Ikeda, unimodal, area-preserving, symplectic, and quadratic maps, center, invariant, stable and unstable, slow, compact, homoclinic, inertial, riemannian, Stiefel, and symplectic manifolds, and normal forms.

Within the Cycling category, the Oscillations sub-category emphasizes oscillators, vibrators, and limit cycles; the Periodicity sub-category emphasizes homoclinic, circular, chaotic, periodic, and quasi-periodic orbits, period doubling, and periodic points; the Wave sub-category emphasizes acoustic, gravity, nonlinear, solitary, spiral, standing, traveling, and water waves, wave equations, fronts, and packets, and wave forms and numbers.

The second level consists of Motion (2571), Scaling (2562), and Modeling and Simulation (1931). The Motion category can be divided into an Evolution sub-category (1218), a Chaos sub-category (554), and an Attractors sub-category (799). The Scaling category can be divided into a Quantum sub-category (1210), a Dimensionality sub-category (491), a Scaling sub-category (739), and a Localization sub-category (122).

Within the Motion category, the Evolution sub-category emphasizes dynamical systems, nonlinear dynamics, chaotic dynamics, time and nonlinear evolution, system and population dynamics; the Chaos sub-category emphasizes chaotic systems, motions, orbits, regimes, states, scattering, and trajectories, onset of chaos, transition to chaos, deterministic chaos, routes to chaos, and spatiotemporal chaos; the Attractors sub-category emphasizes chaotic, global, strange, coexisting, fixed point, periodic, great, hyperchaotic, multiple, random, stable, compact, and dynamical attractors, basins, attracting sets, attractor networks and dimensions.

Within the Scaling category, the Quantum sub-category emphasizes dynamics of small particles [ELECTRONS, IONS, ATOMS, MOLECULES, NUCLEI, PROTONS], lattices, quantum chaos/ dots/ dynamics/ interference/ mechanics/ states/ systems, the Schrodinger equations, and billiard models; the Dimensionality sub-category emphasizes correlation, fractal, embedding, Hausdorff, generalized, range, high and low, and finite dimensions, and degrees of freedom; the Scaling sub-category emphasizes fractals, time and length scales, and self-similarity; the Localization sub-category emphasizes dynamical, nonlinear, spatial, weak, Anderson, and electron localization, intrinsic localized modes, locally transversal linearization, localization length, localized states, and local linearization.

The Modeling and Simulation category emphasizes nonlinear, ordinary and partial differential, stochastic differential, delay differential, functional differential, difference, Navier-Stokes, reaction-diffusion, Fokker-Planck, constitutive, algebraic, Klein-Gordon, KDV, Burger, Euler, Boltzmann, Duffing, Lorenz, Mathieu, and Kuramoto-Sivashinsky equations, equations of motion, control, genetic, numerical, learning, backpropagation, decoding, and Grassberger-Procaccia algorithms, simulated annealing, numerical, computer, dynamical, model, nonlinear, direct, stochastic, monte carlo, and molecular dynamics simulations. and neural network, finite element, nonlinear dynamical, mathematical, numerical, linear and nonlinear, oscillator, chaotic, neuron, circuit, fuzzy, stochastic, mechanical, food chain, and general circulation models.

The third level consists of Communication (1530), Control (1361), Coupling (1375), Thermodynamics (1247), Structures (1100), and Experiment (1073). The Communication category can be divided into a Signals sub-category (1081), a Circuits sub-category (220), a Communications sub-category (136), and a Code sub-category (61). The Coupling category can be divided into a Synchronicity sub-category (591), a Coupling sub-category (319), and a Resonance sub-category (465). The Thermodynamics category can be divided into a Noise sub-category (416), a Statistics sub-category (154), an Entropy sub-category (256), a Dissipation sub-category (303), and a Thermodynamics sub-category (118). The Structures category can be divided into a Nonlinear sub-category (678) and a States sub-category (422).

Within the Communication category, the Signals sub-category emphasizes chaotic, output and input, driving, control, beat, coupled, digital, error, external, microwave, nonlinear, and reference signals, time series, harmonic, anharmonic, and sub-harmonic, information and signal processing, and intermittency; the Circuits sub-category emphasizes electronic, chaotic, equivalent, nonlinear, shunt, and Pikovsky circuits; Josephson Junctions, and switches; the Communications sub-category emphasizes secure, chaotic, digital, and spread spectrum communications, and communication systems, communication channel the Code sub-category emphasizes coding and decoding, encryption, and security.

The Control category emphasizes feedback, delayed feedback, optimal, adaptive, nonlinear, chaos, robust, motion, tracking, active, mode, sliding mode, bifurcation,

variable structure, and hybrid control, feedback, feed-forward, back-propagation, control system/ law/ strategy/ algorithm/ design/ theory.

Within the Coupling category, the Synchronicity sub-category emphasizes phase, chaos, generalized, global, asymptotic, lag, projective, and adaptive synchronization, phase, frequency, mode, and injection locking, discrete breathers, and synchronization error; the Coupling sub-category emphasizes coupled chaotic, coupled systems, coupling strength, strong coupling, weak coupling, and unidirectional coupling; and the Resonance sub-category emphasizes stochastic, internal, parametric, coherence, nonlinear, strong, size, primary, magnetic, cyclotron resonance, and resonance frequencies/ modes/ states. .

Within the Thermodynamics category, the Noise sub-category emphasizes white, gaussian, external, additive, colored, measurement, random, dynamical, channel, correlated, stochastic, and thermal noise, and noise reduction/ intensity/ correlation/ amplitude/ sources, and Brownian Motion; the Statistics sub-category emphasizes Bose-Einstein, Bayesian, Ergodicity, Markov Chain, spectral, eigenvector, and Poisson statistics, and statistical properties/ mechanics/ ensembles/ distributions/ moments/ physics/ theory; the Dissipation sub-category emphasizes energy, tidal, numerical, artificial, and viscous dissipation, dissipative systems/ solitons/ structures/ dynamics/ models/ chaos/ maps, hysteresis; the Entropy sub-category emphasizes Kolmogorov, topological, approximate, information, Neumann, Shannon, linear, maximum, and Tsallis entropy, entropy production/ balance/ correlation/ fluctuations/ flux/ perturbations, spatial, wave, and spatiotemporal patterns, and pattern formation and recognition; the Thermodynamics sub-category emphasizes thermodynamic limits and equilibrium, adiabatic approximation, and nonadiabatic systems and dust .

Within the Structures category, the Nonlinear sub-category emphasizes nonlinear systems/ interactions/ effects/ equations/ response/ terms/ regime/ phenomena/ function/ processes/ elastic/ prediction/ optimization/ stochastic/ viscoelastic/ dependence/ state/ boundary/ crystal/ structure; the States sub-category emphasizes ground, coherent, equilibrium, bound, stationary, excited, transition, basic, system, quiescent, rest and turbulent states, and state variables/ estimation/ vectors. .

The Experiment category emphasizes experimental results/ data/ observations/ measurements/ evidence/ conditions/ models/ verification/ techniques/ apparatus/ device/ dynamics, numerical, laboratory, computer, simulation, independent, and physical experiments, electric, magnetic, and electromagnetic fields, MEMS, microscopy, and spectroscopy,

The remaining categories are small, and will not be discussed further.

4.3.1.2. Statistical Clustering

Two statistically-based clustering methods were used to develop taxonomies, factor matrix clustering and multi-link clustering. Both offer different perspectives on taxonomy

category structure from the non-statistical manual clustering approach described above. None of the three approaches are inherently superior.

Appendix 1 describes the statistically-based clustering methodologies in more detail. Appendix 1A overviews the generic statistically-based clustering approach, Appendix 1B describes the factor matrix clustering, and Appendix 1C describes the multi-link clustering.

4.3.1.2.1. Factor Matrix Clustering

The highest frequency high technical content phrases, with record frequencies not below seven, were identified (640 phrases). Very similar phrases were consolidated (e.g., singulars/ plurals, full spellings/ acronyms, strong synonyms), as shown by the process in Appendix 7. A correlation matrix of the 253 resultant consolidated phrases was generated, and a factor analysis was performed using the WINSTAT statistical package. The eigenvalue floor was set equal to unity, and a factor matrix consisting of 20 factors resulted. A description of each factor, and their aggregation into a taxonomy, follows. The capitalized phrases in parentheses represent typical high factor loading phrases for the factor described. The complete factor matrix is presented in Appendix 8.

Factor 1 (BIFURCATIONS, STABILITY, POINCARE MAPS, PERIODIC MOTIONS, PERIODIC SOLUTIONS, PHASE PLANE, LIMIT CYCLES, PHASE PORTRAITS, FIXED POINTS, PERIOD DOUBLING, EQUILIBRIUM POINTS, also including LYAPUNOV EXPONENTS, NORMAL FORMS, FLOQUET THEORY) – focuses on stability of periodic systems, emphasizing onset and prediction of instabilities. Examines routes to chaos through bifurcation and associated period doubling, using reduced and normal forms of the Poincare map, as well as phase plane trajectories to plot the motions.

Factor 2 (CLASSICAL SYSTEM, CLASSICAL LIMIT, QUANTUM SYSTEMS, QUANTUM DYNAMICS, TRACE FORMULA, QUANTUM MECHANICS, TIME EVOLUTION, CLASSICAL DYNAMICS, DYNAMICAL EVOLUTION, BROWNIAN MOTION, also including QUANTUM-CLASSICAL CORRESPONDENCE, DECOHERENCE, COHERENT STATES) – focuses on correspondence between quantum dynamical systems and classical systems, especially focusing on the classical limit behavior of quantum systems, as well as the trace formula's semiclassical representation for a quantum system's density of states in terms of the periodic orbits of the underlying classical dynamics.

Factor 3 (RANDOM MATRIX THEORY, ENERGY LEVELS, SPECTRAL STATISTICS, STATISTICAL PROPERTIES, EIGENFUNCTIONS, QUANTUM-CLASSICAL CORRESPONDENCE, ERGODICITY, WAVE FUNCTIONS, also including CHAOS, PERIODIC ORBITS, QUANTUM DOTS) – focuses on potential links between the statistical distribution of the energy levels of classically chaotic systems and the

eigenvalue correlations of random matrix theory, or between the quantum properties of individual deterministically chaotic systems and of ensembles of randomly disordered systems.

Factor 4 (BASINS, ATTRACTORS, INVARIANT SUBSPACE, COUPLED CHAOTIC SYSTEMS, INTERMITTENCY, SYMMETRY BREAKING, MANIFOLDS, also including FRACTALS, SCALING, INVARIANT SETS, GLOBAL DYNAMICS, BIFURCATIONS, PHASE PLANE) – focuses on formation of riddled basins (every point in a chaotic attractor's basin has pieces of another attractor's basin arbitrarily nearby) and off-on intermittency by the loss of transverse stability of an invariant subspace containing a chaotic attractor; examines the effect of perturbation-induced symmetry-breaking on blowout-bifurcations (accompanying Lyapunov exponent sign reversal) that create riddled basins.

Factor 5 (SYNCHRONIZED, FREQUENCY DETUNING, FEEDBACK, COUPLING, LASERS, NOISE, GENERALIZED SYNCHRONIZATION, PHASE LOCKING, COHERENCE RESONANCE, DRIVE SYSTEM, CHUA'S C'RCUIT, LORENZ SYSTEM, INFORMATION SIGNAL, CHAOTIC DYNAMICAL SYSTEMS, also including WEAKLY NONLINEAR ANALYSIS, PATTERN FORMATION, CHAOS, NEURAL NETWORKS, NEURONS, OSCILLATORS) – focuses on synchronization of chaotic dynamical systems, especially optically coupled diode lasers with optical feedback, and examines synchronization robustness with respect to frequency detuning.

Factor 6 (LYAPUNOV EXPONENTS, POWER SPECTRUM, CORRELATION DIMENSIONS, TIME SERIES, KOLMOGOROV ENTROPY, FRACTALS, HEART RATE, SPECTRAL ANALYSIS, CIRCULAR ORBIT, also including ATTRACTORS, INTERMITTENCY, NOISE, CHAOS, POWER LAW, FREQUENCY DOMAIN, TIME DOMAIN, SYSTEM DYNAMICS, POINCARE MAPS, PHASE PLANE, PHASE PORTRAITS) – focuses on application of chaos metrics/ tools (Lyapunov exponents, power spectra, correlation dimension, fractals) to time series, especially from heart and brain wave generators, to fully characterize the nonlinear dynamical components of the signal.

Factor 7 (SCALING, MODULATION EQUATIONS, NORMAL FORMS, PARAMETRIC EXCITATION, LINEAR ANALYSIS, LAGRANGIAN, HOMOCLINIC, FLOQUET THEORY, also including BIFURCATIONS, STABILITY, LIMIT CYCLES, PERIOD DOUBLING, INTERMITTENCY, HOMOCLINIC ORBITS, DUFFING OSCILLATOR) – focuses on use of multiple scales to derive modulation equations (mainly Ginzburg-Landau equations expressing time variation of amplitude and phase), in standard normal form of low co-dimension bifurcations.

Factor 8 (VISCOSITY, WEAKLY NONLINEAR ANALYSIS, FLUID DYNAMICS, SURFACE TENSION, REYNOLDS NUMBERS, ANGULAR VELOCITY, GLOBAL EXISTENCE, PATTERN FORMATION, FREE SURFACE, STEADY-STATE, SHEAR, also including STABILITY, FREQUENCY DETUNING, AMPLITUDE EQUATIONS, FREQUENCY DOMAIN, TIME DOMAIN,) – focuses on dynamics of fluids where

viscosity and surface tension are important (fluid-fluid and fluid-surface interactions, as well as some cases of free-surfaces). Examines stability and pattern formation as functions of different dimensionless parameters (Reynolds Numbers, Weber Number, Bond Number).

Factor 9 (CHAOS, NEURAL NETWORKS, NEURONS, MAPS, COMPLEX SYSTEMS, also including POINCARE MAPS, LIMIT CYCLES, TIME EVOLUTION, STATISTICAL PROPERTIES, ATTRACTORS, SYNCHRONIZED, LORENZ SYSTEM, LYAPUNOV EXPONENTS, CONTROLS, PHASE SPACE, INITIAL CONDITIONS, CHAOTIC DYNAMICS, STATE SPACE, LOCAL DYNAMICS) – focuses on nonlinear dynamics of coupled neurons in complex networks, emphasizing the use of coupled maps exhibiting chaotic oscillations to simulate the network behavior.

Factor 10 (ANGULAR MOMENTUM, TOTAL ENERGY, POWER LAW, NATURAL FREQUENCY, LOCAL MINIMA, FLUCTUATIONS, VORTICITY, also including CLASSICAL SYSTEM, TRACE FORMULA, STATISTICAL PROPERTIES, QUANTUM-CLASSICAL CORRESPONDENCE, TOPOLOGY) – focuses on major integrals of motion of interacting systems described by power law distribution spectra, especially in the transition regime between integrability and chaos.

Factor 11 (EXTERNAL DISTURBANCES, CONTROLS, PARAMETRIC UNCERTAINCIES, SYSTEM RESPONSE, FRICTION, NONLINEAR DYNAMICAL SYSTEMS, MECHANICAL SYSTEMS, DYNAMIC RESPONSE, OPTIMAL CONTROL, NONLINEARITY, CLOSED-LOOP SYSTEM, CONSTANT VELOCITY, RELATIVE MOTION, DYNAMIC PROPERTIES, also including MODELS, SYSTEM PARAMETERS, NEURAL NETWORKS) – focuses on adaptive robust control of nonlinear dynamical systems subject to external disturbances and parametric uncertainties, with emphasis on mechanical systems such as robots and automobiles.

Factor 12 (HOMOCLINIC ORBITS, PERIODIC ORBITS, TOPOLOGY, PHASE SPACE, SCALAR FIELD, HAMILTONIAN SYSTEMS, CRITICAL POINTS, INITIAL CONDITIONS, ANISOTROPY, VECTOR FIELDS, SINGULARITY, INVARIANT SETS, CHAOTIC DYNAMICS, DUFFING OSCILLATOR, also including POINCARE MAPS, PHASE PLANE, ATTRACTORS, NORMAL FORMS, HOMOCLINIC, MAPS, SYSTEM DYNAMICS) – focuses on orbits for which the stable and unstable manifolds intersect, especially those accompanied at small values of the bifurcation parameter by the existence of a countable set of periodic and an uncountable set of aperiodic solutions (i.e., chaotic structure) in the proximity of the homoclinic.

Factor 13 (DIFFUSION COEFFICIENT, HAUSDORFF DIMENSION, EQUILIBRIUM STATE, RELAXATION, COMPLEX PLANE, LONG-TIME BEHAVIOUR, FIELD LINES, TIME DEPENDENCE, also including EIGENFUNCTIONS, LYAPUNOV EXPONENTS, FRACTALS) – focuses on relations between transport coefficients and chaotic properties for systems relaxing to equilibrium, emphasizing the relation between the diffusion coefficient and the fractality (the Hausdorff Dimension and the Lyapunov exponent) of the hydrodynamic modes of transport.

Factor 14 (EXPONENTIAL DECAY, DECOHERENCE, TOPOLOGICAL ENTROPY, COHERENT STATES, CLOSED ORBITS, ESSENTIAL SPECTRUM, AMPLITUDE EQUATIONS, CONVERGENCE PROPERTIES, PROBABILITY DISTRIBUTIONS, PHASE TRANSITION, also including CLASSICAL SYSTEM, EIGENFUNCTIONS, MUTUAL INFORMATION) –. focuses on decoherence effects of environment and detectors on quantum systems, whose classical correspondents are chaotic, and relates the decay function of the decoherence effect to the purely exponential decay characteristic of chaotic motion.

Factor 15 (ENTROPY, MUTUAL INFORMATION, THERMODYNAMICS, SPEECH, LONG TIME, POPULATION DYNAMICS, CORRELATION FUNCTION, also including QUANTUM MECHANICS, CLASSICAL DYNAMICS, LYAPUNOV EXPONENTS, CORRELATION DIMENSIONS, MAPS, TOPOLOGICAL ENTROPY, QUANTUM DOTS) – focuses on the use of mutual information between random variables and information theory analogues of thermodynamic entropy to analyze system dynamics and time series, in order to indicate structure or correlation and quantify informatioon content.

Factor 16 (FREQUENCY DOMAIN, TIME DOMAIN, DIFFERENTIAL EQUATIONS, FOURIER, SYSTEM DYNAMICS, ASYMPTOTIC EXPANSION, LINEAR SYSTEMS, REAL TIME, PERIODICITY, STATE SPACE, DIFFERENCE EQUATIONS, also including LIMIT CYCLES, FIXED POINTS, COMPLEX BEHAVIOR, TRACE FORMULA, TIME SERIES, CONTROLS, CONVERGENCE PROPERTIES) – focuses on control of limit cycle oscillations in dynamical systems, emphasizing time series analyses (e.g., convolutions) in the time domain, then Fourier transforms of time series into frequency domain, and subsequent frequency domain analyses.

Thus, the 16 factors can be viewed as thrust areas constituting the lowest level taxonomy. Each factor contains one or more of the following elements: 1) Sub-system –specific (e.g., neurons); 2) System-specific (e.g., brain); 3) System-generic (e.g., biological systems); 4) Phenomenon (e.g., bifurcations). Thus, there are myriad ways to combine the factors, depending on which dominant characteristics are chosen. In practice, the aggregation methodology will depend on the application for the taxonomy. For example, if the taxonomy is used to identify participants for a comprehensive workshop on Nonlinear Dynamics sources, categorizing by phenomena would identify e.g., mapping experts, while categorizing by system would identify e.g. laser experts. Selection of aggregation attributes would depend on the workshop objectives. Conversely, assume the taxonomy is used by a program manager to estimate global levels of effort in specific technologies, in order to identify technology areas of adequacy and deficiency. Then, categorizing by phenomena would identify e.g., mapping deficiencies, whereas categorizing by system would identify e.g., laser deficiencies.

The factors above were aggregated by phenomena, using the higher level categorical structuring described in the next section. The following hierarchical level taxonomy resulted (numbers in parenthesis are factor numbers from above).

The highest level taxonomy consists of:

IA-Chaotic Motion

IB-Nonlinear Systems Concepts not necessarily linked to Chaotic Motion

The next highest level taxonomy consists of:

IA1-Characteristics and analysis tools for chaotic systems
(1, 3, 4, 6, 12, 13)

IA2-Synchronization and control of coupled systems
(5, 9)

1B1-Analytic tools for nonlinear analysis of specific applications
(8, 11)

IB2-Methods to simplify solutions of high dimensional nonlinear equations
(2, 7, 10, 14, 15, 16)

4.3.1.2.2. Multi-Link Clustering

A symmetrical co-occurrence matrix of the 253 highest frequency high technical content phrases was generated. The matrix elements were normalized using the Equivalence Index (Eij=Cij^2/Ci*Cj, where Ci is the total occurrence frequency of the ith phrase, and Cj is the total occurrence frequency of the jth phrase, for the matrix element ij), and a multi-link clustering analysis was performed using the WINSTAT statistical package. The Average Linkage method was used. Three types of raw data output were generated by each clustering run: a dendogram, a table, and a taxonomy. These three types of data output are described in detail in Appendix 1. The final 253 phrase dendogram is shown in Appendix 8. A description of the final dendogram, and the aggregation of its branches into a taxonomy of categories, follows. The capitalized phrases in parentheses represent cluster boundary phrases for each category.

The 253 phrases in the dendogram are grouped into 26 clusters. These clusters form the lowest level of the taxonomy hierarchy. Each cluster is assigned a letter, ranging from A to Z. The cluster hierarchies are determined by the branch structure. Overall, there are two main branches (clusters). Starting from the phrase adjoining the 'distance' ordinate, the first main cluster (A-M) ranges from MODELS to COMPLEX SYSTEMS. The second main cluster (N-Z) ranges from NONLINEAR PHENOMENA to TIME INTERVALS. While the total dendogram reflects different aspects of nonlinear dynamics, the first cluster (A-M) covers different aspects of chaotic motion, while the second cluster (N-Z) covers nonlinear system concepts with no specified links to chaotic

motion. Each of these large clusters will be divided and sub-divided into smaller clusters, and discussed.

Cluster (A-M) can be divided into clusters (A-I) and (J-M). Cluster (A-I) ranges from MODELS to LINEAR SYSTEMS, and cluster (J-M) ranges from OSCILLATORS to COMPLEX SYSTEMS. Cluster (A-I) focuses on general characteristics of, and tools used to analyze, chaotic systems, while cluster (J-M) focuses on the synchronization and control of coupled systems subject to noise and other external disturbances.

Cluster (N-Z) can be divided into clusters (N-V) and (W-Z). Cluster (N-V) ranges from NONLINEAR PHENOMENA to CHAOTIC INFLATION, and cluster (W-Z) ranges from PERIODIC ORBITS to TIME INTERVALS. Cluster (N-V) focuses on the use of analytical tools (Fokker-Plank equation, Galerkin method, finite element method) for the nonlinear analysis of specific applications (aircraft vorticity, earthquakes, fluid dynamics, speech), and cluster (W-Z) focuses on methods to simplify solutions of high dimensional nonlinear equations (e.g., correspondence of quantum and classical systems, power law approximations, time domain-frequency domain transforms).

Cluster (A-I) can be subdivided into clusters (A-F) and (G-I) Cluster (A-F) ranges from MODELS to SCALAR FIELD, and focuses on analysis tools for, and characteristics of, chaotic systems. Cluster (G-I) ranges from MAPS to LINEAR SYSTEMS, and incorporates phenomena associated with chaotic and non-chaotic systems. Each of these clusters can now be divided into its elemental clusters.

Cluster A (MODELS to LAGRANGIAN) focuses on stability of periodic systems, emphasizing onset and prediction of instabilities; models periodic motions of dynamic systems to identify bifurcations that alter the stability of fixed points into limit cycles; uses multiple scales to derive modulation equations (mainly Ginzburg-Landau equations expressing time variation of amplitude and phase), in standard normal form of low codimension bifurcations.

Cluster B (PERIODIC SOLUTIONS to CONTINUATION METHOD) focuses on stability analysis and routes to chaos, using bifurcation diagrams, reduced and normal forms of the Poincare map, phase portraits, as well as phase plane trajectories to plot the motions.

Cluster C (HOMOCLINIC ORBITS to CIRCULAR ORBITS) focuses on periodic solutions near the homoclinic orbit of the Duffing oscillator with small perturbations, and on the conditions under which chaotic orbits can occur.

Cluster D (CHAOS to MODULATION FREQUENCY) focuses on application of chaos metrics/ tools (Lyapunov exponents, power spectra, correlation dimension, fractals) to time series, especially from heart and brain wave generators, to fully characterize the nonlinear dynamical components of the signal.

Cluster E (ATTRACTORS to COUPLED CHAOTIC SYSTEMS) focuses on formation of riddled basins (every point in a chaotic attractor's basin has pieces of another attractor's basin arbitrarily nearby) and off-on intermittency by the loss of transverse stability of an invariant subspace containing a chaotic attractor; examines the effect of perturbation-induced symmetry-breaking on blowout-bifurcations (accompanying Lyapunov exponent sign reversal) that create riddled basins.

Cluster F (INITIAL CONDITIONS to SCALAR FIELD) focuses on system dynamical evolutions based on initial conditions, and examines the topology of local and global dynamics in the phase space.

Cluster G (MAPS to DYNAMICAL EVOLUTION) focuses on chaotic maps with an invariant measure, the conditions under which period doubling is present on the route to chaos, and the fractality of the chaotic attractor.

Cluster H (DYNAMIC PROPERTIES to STOCHASTIC) focuses on dynamic properties of periodic orbits and chaotic attractors, and includes the use of maps to allow calculations of the location and stabilities of the periodic points in the chaotic attractor.

Cluster I (DIFFERENTIAL EQUATIONS to LINEAR SYSTEMS) focuses on the equations used to describe dynamical systems, and on the parameter-dependent periodic windows in the chaotic motions in which non-chaotic motion may be found.

Cluster (J-M) can be divided into its elemental clusters.

Cluster J (OSCILLATORS to INFORMATION SIGNAL) focuses on synchronization of chaotic dynamical systems, especially optically coupled diode lasers with optical feedback, and examines synchronization robustness with respect to frequency detuning.

Cluster K (SYSTEM DYNAMICS to DETERMINISTIC DYNAMICS) focuses on dynamics of chaotic systems (especially biological) in the presence of noise, including noise-enhanced temporal regularity, leading to determination of the vector field of the chaotic dynamics.

Cluster L (CONTROLS to THEORETICAL MODEL) focuses on adaptive robust control of nonlinear dynamical systems subject to external disturbances and parametric uncertainties, with emphasis on mechanical systems such as robots and automobiles.

Cluster M (NEURAL NETWORKS to COMPLEX SYSTEMS) focuses on use of neural networks to simulate brain subsystems, and the impact of both neuron models and temporal and spatial correlations in neuronal activity on the simulation strength of the neural network.

Cluster (N-V) may be divided into its elemental clusters, and cluster (W-Z) may be divided into its elemental clusters.

Cluster N (NONLINEAR PHENOMENA to ENERGY TRANSFER) focuses on nonlinear phenomena in aircraft flight, such as limit cycle oscillations, and the role of flow-field vortices in these fluid-structure oscillatory phenomena.

Cluster O (QUASIPERIODIC to NORMAL MODES) focuses on solving for velocity distributions and other variables of continuum flows in bounded regions with surface friction, using the Galerkin integral approach to solve the equations; solving for velocity distributions and other variables of particle flows in unbounded regions with inter-particle friction, using the Fokker-Planck kinetic equations to solve the equations; solving for structural dynamic responses to relative motions induced by to earthquakes, using finite element techniques.

Cluster P (FLUID DYNAMICS to ESSENTIAL SPECTRUM) focuses on fluid dynamics of partially or fully unbounded flows at different Reynold's Numbers, where surface tension at the free surface tends to increase instabilities and the fluid viscosity tends to reduce instabilities; population dynamics (mainly smaller animal species), emphasizing self-organization and pattern formation.

Cluster Q (IONS to MULTIPLE SOLUTIONS) focuses on quantum dots (semiconductor nanoparticles) and their structural and interaction similarities to large molecules and ions; the use of mutual information between random variables and information theory analogues of thermodynamic entropy to analyze system dynamics and time series, in order to indicate structure or correlation and quantify information content.

Cluster R (CALCULATIONS to NONLINEAR EQUATIONS) focuses on flows in heated channels, and the onset of instabilities as a function of channel aspect ratio and Rayleigh Number.

Cluster S (MAGNETIC FIELDS to LONG-TIME BEHAVIOR) focuses on transport coefficients across and parallel to ambient magnetic field lines in turbulent flows, both in space and fusion-driven plasmas; dissipative fluid flow systems, with turbulent kinetic energy and shear; relations between transport coefficients and chaotic properties for systems relaxing to stationary states, emphasizing the relation between the diffusion coefficient and the fractality (the Hausdorff Dimension and the Lyapunov exponent) of the hydrodynamic modes of diffusion.

Cluster T (STEADY STATE to SPATIAL DISTRIBUTION) focuses on steady-state CO oxidation over Pd or Pt catalysts, including regular, chaotic, or mixed mode reaction rate oscillations driven by mass transfer limitations or external parameter variations.

Cluster U (RESONANCES to CONSTITUTIVE EQUATIONS) focuses on linear approximations to constitutive rheological equations to study temporal evolution of stress and other interface phenomena, emphasizing interface phenomena resonances as a function of parameter variations.

Cluster V (GROUND STATE to CHAOTIC INFLATION) focuses on changes in ordering of layers of molecule-sized particles, as a function of temperature and film thickness; chaotic conditions for chaotic nature of radiation emitted from black hole candidates, and energy spectra of this radiation.

Cluster W (PERIODIC ORBITS to TOTAL ENERGY) focuses on trace formulas, which in general relate the density of states for a given quantum mechanical system to the properties of the periodic orbits of its classical counterpart (quantum-classical correspondence); potential links between the statistical distribution of the energy levels of classically chaotic systems and the eigenvalue correlations of random matrix theory, or between the quantum properties of individual deterministically chaotic systems and of ensembles of randomly disordered systems; major integrals of motion of interacting systems described by power law distribution spectra, especially in the transition regime between integrability and chaos.

Cluster X (BOUNDARY CONDITIONS to DECOHERENCE) focuses on the influence of boundary conditions on the evolution of coherent structures in pattern formation, using the Ginzburg-Landau form of the amplitude equations.

Cluster Y (TIME DOMAIN to OPTIMAL CONTROL) focuses on control of limit cycle oscillations in dynamical systems, emphasizing time series analyses (e.g., convolutions) in the time domain, then Fourier transforms of time series into frequency domain, and subsequent frequency domain analyses; also establishes optimal control conditions for pertubed systems using ergodicity assumptions.

Cluster Z (SYMBOLIC DYNAMICS to TIME INTERVALS) focuses on decoherence effects of environment and detectors on quantum systems, whose classical correspondents are chaotic, and relates the decay function of the decoherence effect to the purely exponential decay characteristic of chaotic motion; use of topological methods to support symbolic dynamics, show existence of closed orbits, and estimate topological entropy.

4.3.1.3. High Frequency Low Frequency Phrase Relationships

The statistical taxonomies were based on symmetrical matrices of relatively high frequency phrases, and the manual taxonomies made some use of mid-frequency phrases. Clustering also allows high frequency phrases to be related to low frequency phrases through the use of symmetric and non-symmetric matrices. The following example is motivated by one of the bibliometrics results.

It was found that China's ranking as a prolific producer of nonlinear dynamics' research papers increased substantially over the past decade. It might be useful to identify their technology focus areas. In particular, it would be interesting to identify some technology areas in nonlinear dynamics in which the U. S. is a major player and China a minor player, and vice versa.

A non-symmetric Abstract phrase-country matrix was generated using the Abstract phrases and countries generated by the ACCESS template. All the countries were included, and Abstract phrases with a frequency of three or greater were included. The matrix elements' values reflected the number of records in which Abstract phrase x co-occurred with country y.

Only the columns for China and the USA were analyzed. The raw data phrases in the China column were normalized (multiplied by approximately three), such that the total number of China's 2001 records was set equal to the total number of USA 2001 records. The phrases in these two columns were compared, and the ratio of record frequencies for China's phrases to those of the USA was used as a comparison metric. This ratio ranged from infinity (finite occurrences in the China column, zero occurrences in the USA column) to zero (zero occurrences in the China column, finite occurrences in the USA column. The number of phrases in the different bands of the comparison metric is shown in Table 11.

TABLE 11 – RATIO OF RECORDS WITH SELECTED PHRASES IN NONLINEAR DYNAMICS CHINA/ USA LITERATURE – 2001

METRIC BAND	# PHRASES
INFINITY	1238
9 TO 25	138
.11 TO 9	7057
.05 TO .11	34
0	10686

There were a total of 19153 candidate phrases. For the present purpose of identifying major asymmetries, only the phrases with very high or very low record frequency ratios (the wings of the distribution function) were examined. Of this subset, only the phrases above a threshold of record frequencies were considered.

Table 12 contains phrases that met the numeric criteria (above), appeared to be significant technically, and, for the USA-predominant phrases in particular, appeared to be part of a pattern.

TABLE 12 – PHRASES WITH VERY HIGH OR LOW CHINA/ USA RECORD FREQUENCY RATIOS

PHRASE	CHINA RAW-DAT	USA	CHINA NORM	RATIO CH/ US
WEAK EXTERNAL NOISE	3	0	9.17	INF
DUAL-RING LASER	3	0	9.17	INF
ERBIUM-DOPED FIBER	3	0	9.17	INF

EXTERNAL NOISE	8	1	24.45	24.45
NOISE INTENSITY	6	1	18.34	18.34
GAUSSIAN WHITE NOISE	3	1	9.17	9.17
SEISMIC	1	18	3.06	0.17
NAVIER-STOKES	1	22	3.06	0.14
SEA	1	24	3.06	0.13
VORTICITY	1	25	3.06	0.12
MAGNETIC	3	76	9.17	0.12
SOLAR	1	26	3.06	0.12
OCEAN	1	29	3.06	0.11
SEMICONDUCTOR	1	32	3.06	0.10
MAGNETIC FIELD	0	51	0	0
FRONTS	0	20	0	0
ORBITAL	0	16	0	0
BOUNDARY LAYER	0	16	0	0
PACIFIC	0	15	0	0
BROWNIAN	0	15	0	0
AERODYNAMIC	0	15	0	0
CURRENTS	0	13	0	0
MAGNETIC FIELDS	0	13	0	0
MAGNETOHYDRODYNAMIC	0	13	0	0
SEMICONDUCTOR LASERS	0	12	0	0
AIRCRAFT	0	12	0	0
AEROELASTIC	0	12	0	0
ICE	0	12	0	0
RAYLEIGH NUMBER	0	11	0	0
ENCODING	0	11	0	0
GALAXIES	0	10	0	0
BROWNIAN MOTION	0	9	0	0
NINO	0	8	0	0
STELLAR	0	8	0	0
BLACK HOLE	0	8	0	0
DIELECTRIC	0	8	0	0
EL NINO	0	8	0	0
MESOSCALE	0	8	0	0
SEDIMENT	0	7	0	0
SEMICONDUCTOR LASER	0	7	0	0
TROPOSPHERE	0	7	0	0
DECODING	0	7	0	0
BLACK HOLES	0	7	0	0
GALACTIC	0	7	0	0
TELESCOPE	0	6	0	0
BAROTROPIC	0	6	0	0
DEEP WATER	0	6	0	0

SEDIMENTS	0	5	0	0
SHALLOW-WATER	0	5	0	0
TRANSONIC	0	5	0	0
TROPOSPHERIC	0	5	0	0
WATER DEPTH	0	5	0	0
WIND-TUNNEL	0	5	0	0
ASTROPHYSICAL	0	5	0	0
ANGLE OF ATTACK	0	5	0	0
INTERSTELLAR	0	5	0	0
GALAXY	0	5	0	0

In Table 12, the leftmost column is the phrase of interest, the next column is number of China records in which the phrase appears, the next column is number of USA columns in which the phrase appears, the next column is the normalized China column, and the rightmost column is the ratio of the normalized China column matrix element to the USA column matrix element. The distribution in Table 12, as well as in the raw data, is asymmetric. There are many more phrases that appear predominately in USA records than predominately in China records.

The first six phrases in Table 12 are those that predominate in China records. The only pattern appears to focus on noise. While the phrase NOISE is about equally distributed between China and USA records in the raw data, some variants predominated in the China records, as shown in Table 12.

The remainder of the phrases in Table 12 are those that predominate in USA records. Perhaps the most surprising is MAGNETIC FIELD(S). For the 2001 database, there are 64 USA records that contained MAGNETIC FIELD(S), and no China records. A sampling of these USA records showed them to be of two generic types. The dominant type addressed the nonlinear dynamics of magnetic fields in space plasmas, and the other type addressed the nonlinear dynamics of magnetic fields in controlled magnetic fusion systems. These applications areas require large experimental and flight facilities to conduct research and obtain data. The USA has large efforts in both areas, whereas China has minimal efforts in both. Other USA-dominant phrases from Table 12 relate to space research support this reasoning (SOLAR, GALAXIES, STELLAR, BLACK HOLE(S), TROPOSPHERE, GALACTIC, TELESCOPE, ASTROPHYSICAL, INTERSTELLAR, GALAXY).

Two major caveats on the data in Table 12 should be emphasized. First, only phrases above the threshold frequency were considered for the candidate phrase pool. Thus, phrases that have zero frequency in Table 12 could in fact have a very low, but finite, frequency. Second, the phrases for the co-occurrence computations were restricted to the Abstracts only. Thus, phrases that occurred in the Keywords or Title were not included.

Other topical areas with patterns of USA predominance include oceanography and weather (SEA, OCEAN, FRONTS, PACIFIC, ICE, EL NINO, MESOSCALE,

SEDIMENT, BAROTROPIC, DEEP WATER, SHALLOW-WATER, WATER DEPTH), aerodynamics (NAVIER-STOKES, VORTICITY, BOUNDARY LAYER, AERODYNAMIC, AIRCRAFT, AEROELASTIC, WIND-TUNNEL, ANGLE OF ATTACK), semiconductors (SEMICONDUCTOR, SEMICONDUCTOR LASER (S)), and encryption (ENCODING, DECODING). In fact, perusal of the lower frequency raw data terms relating to coding shows almost no phrases in any of the variants in the China literature. Again, many of the oceanography/ weather-related papers reflect large-scale experimental programs, from which more data would be available to a developed nation than a developing nation.

Because of the two caveats on the numbers in Table 12 presented previously, the phrases discussed above that reflected areas of USA dominance relative to China were inserted into the SCI, to validate the results. All the fields were examined, with no threshold on phrase frequency. The USA still predominated heavily, by a factor of about five relative to the normalized China frequencies. Thus, the simple method presented here provides the correct order of magnitude answer, but the actual ratio values are overly optimistic. In fact, this combination of using the simple method to identify major technical emphasis differences between countries, followed by a more targeted and detailed analysis of the SCI, is probably a reasonable prototype for a production-level analysis.

While these examples and the associated analysis are very abbreviated due to space limitations, the capability offered is intrinsically very powerful. The high frequency phrase/ low frequency phrase relational technique allows a microcasm of the total text mining study to be performed for any high frequency phrase, or combination of high frequency phrases. When relational indicators are used (not shown in this example), tens, or even hundreds, of low frequency phrases can be identified as relating to a high frequency phrase (depending on the total number of phrases used, and the threshold values of the numerical relational indicators chosen). These low frequency phrases can be categorized into a taxonomy, allowing the technical and bibliometric infrastructure for the high frequency phrase/ concept to be obtained.

4.3.1.4 Recommended Taxonomy

The different statistical and non-statistical taxonomies generated above used different methodologies and some different phrases. Therefore, the results are not directly comparable. A taxonomy that reflects the levels of effort and specific research thrusts would have the structure of the non-statistical Abstract field taxonomy. A taxonomy that reflects commonality of categories would have the structure of the statistical taxonomies.

4.4 Final Observations on Results

This section addresses balance or imbalance of Nonlinear Dynamics with respect to different parameters.

A) Type of Research
In contrast to many of the previous topical text mining studies performed, Nonlinear Dynamics appears to be balanced among theory, experiment, and computational modeling. There is substantial phrase representation in all these research segments.

B) Categories of Research
Compared to most text mining studies performed previously by the first author, Nonlinear Dynamics seems heavily weighted toward basic research. No applied research journals were evident. No companies appeared in the institutional production category, and the only industry appearance was reflected by one of the most cited authors.

However, given the large volume of research activity, the discipline appears poised to transition into applications. There is already ongoing work on antennas, detectors, thermal combustors, and high power lasers that should find its way eventually to industry. The six volumes of experimental papers (not contained in the SCI) from the Proceedings of the Experimental Chaos conference (17-22) provide some indication of the breadth of potential applications.

C) Applications vs Tech Base
There appears to be a reasonable balance between generic tech base studies and more focused areas. Based on the journals and author institutions as stated above, as well as the types of phrases obtained, the focused area studies are more at the basic research level than applied.

Overall, there is a reasonable balance between chaos-oriented phenomena and nonlinear phenomena with no specified links to chaotic motion. Further, there appears to be a reasonable balance among techniques for analyzing chaotic systems, techniques for synchronizing and controlling coupled systems, and use of analytical tools for the nonlinear analysis of specific applications. Progress on methods to simplify solutions of high dimensional nonlinear equations, or on spatio-temporal (infinite dimensional) systems, has been slower.

Within the tech base areas, the priorities seem reasonable. Major emphasis is given to stability and cycling, reasonable emphasis is given to motion, scaling, modeling and simulation, and moderate emphasis is given to communication, control, coupling, thermodynamics, structures, and experiment. Hard divisions among many of these categories are somewhat blurred, because of overlap and potential multiple category assignment of phrases.

Within the focused areas, there is a reasonable balance among physical, environmental, engineering, and life sciences. However, there is a substantial imbalance between the 'hard' and 'soft' sciences. Essentially nothing in the phrase pattern analysis reflected input from the true social and political sciences. The number of articles retrieved from the Social Science Citation Index was four percent of the total articles retrieved. A reading of these 'social science' articles showed that: 1) 'chaos' is

used in the vernacular in a not-insignificant fraction; 2) neuroscience and psychiatry/ psychology have reasonable representation, but they were captured in the phrase pattern analysis; 3) there is some effort on financial markets, but too widespread to generate high or mid-frequency phrase outputs; 4) there is minimal effort in the true social and political sciences.

One objective of the present study was to understand the applicability of Nonlinear Dynamics to political trends and predictions. Because chaos applies to deterministic equations, its applications to social systems are problemmatical, since social systems are too noisy to define deterministic trajectories. Too much information is missing in social/ economic systems to model the system accurately enough to find chaos, although other nonlinear responses are apparent. For example, the stock market has dramatic changes, and WWI started over a single assassination.

The documented applications in these social science areas are minimal. There may be a variety of causes in addition to noisy data mentioned above. In the present high tech world economy, both commercial and military, research sponsoring organizations may be far more interested in pursuing ‘hard’ science applications of Nonlinear Dynamics than ‘soft’ science applications.

Thus, money for social and political science research in Nonlinear Dynamics may not be available. In addition, because of potential sensitivities of political and social structure dynamics and trends, Nonlinear Dynamics studies may in fact be ongoing, but not published in the open literature. Given the inherent strong feedback and non-linearities in social group situations and organizations at all levels, one would expect that Nonlinear Dynamics could provide useful insights for analyzing and predicting social and political trends.

At a minimum, some of the concepts of Nonlinear Dynamics may be useful to ‘softer’ science applications, including bifurcations of behaviors, extreme sensitivity to initial conditions, pattern formation, attractors, repellers, and orbits. For example, there is an effort at ONR in war gaming based on cellular automata that has aspects of pattern formation (complexity) arising from simple rules. Flanking maneuvers appear, but have not been explicitly programmed. For all practical purposes, applicability of Nonlinear Dynamics to the ‘softer’ sciences remains unexplored.

D) Regional

Most previous text mining studies have shown the USA to be dominant in research output, and the Nonlinear Dynamics study is no exception. However, the difference between the USA and the other producers appears to be greater. This imbalance has been reduced over the past decade, from a factor of four greater than its nearest competitor to a factor of three, but it is still substantial. China has ascended as a major competitor, but does not appear to be involved in major areas in which the USA is not working. There is a reasonable balance between Europe and Asia, but still a substantial under-representation from the developing nations.

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6. APPENDICES

APPENDIX 1 – CLUSTERING METHODOLOGIES

Phrase clustering is the grouping of word strings by similarity to some metric. When applied to technical literature (unstructured technical text), it produces groups of technical thrusts. The phrase members of each thrust grouping are related to the group's theme. When applied to a bibliometric list, such as a list of technical paper authors, it produces groups of bibliometric quantities (e.g., authors). In the author case, the authors of each group would have some common similarity, depending on the metric chosen. For example, the groups could be defined by people who publish together, or people who work at the same institution, or people who work in the same topical area.

In the present paper, three phrase clustering approaches are used. One approach is non-statistical, and the other two are statistical. Each approach has the same type of starting point. Text to be analyzed is assembled, either from unstructured free text (e.g., reports, databases with free text fields, etc), or databases with bibliometric fields (e.g., databases of journal papers with author name fields, author institution fields, journal fields, etc). The text to be analyzed is then converted to phrases, with a frequency of occurrence associated with each phrase. The physical locations of the phrases in the source documents are retained, so that this co-occurrence information can be exploited in the grouping process. Now, each of the grouping/ clustering methods will be described in detail.

1A. Non-Statistical Clustering

In this paper, TextDicer, successor to the TextSlicer software (associated with the Database Tomography process and system), was used for the non-statistical clustering <u>phrase frequency analysis</u>. This software generates the frequencies of <u>all</u> single and adjacent double and triple (and, recently, quadruple) word high technical content phrases contained in databases of interest. It allows multiple counting of nested phrases (i.e., for the double-word phrase METAL MATRIX, METAL is counted as a single word phrase, MATRIX is counted as a single word phrase, and METAL MATRIX is counted as a double word phrase). Through visual inspection and subsequent manual grouping of the technical phrases by technical experts, taxonomies of each database analyzed are then generated, in order to ascertain the specific technical emphases of each database. Two main criteria are employed to select taxonomy categories. First, the categories should be relatively independent and, in aggregate, should allow for rational allocation of all the phrase frequency data. Second, a balance is required between the unwieldiness of too many categories and the insufficient discrimination of too few categories. To quantify the technical emphases, phrases and their associated frequencies of occurrence are binned into the appropriate taxonomy categories based on the expert analyst's judgement. The frequencies of the phrases in each category are summed to provide some estimate of relative levels of global emphasis of each category.

In the present study, and in all studies that have some specific technical focus, two generic types of high technical content phrases result. One type is application or technology specific (e.g., lasers, fluid turbulence). The other type is applicable to multiple systems or applications (e.g., period doubling, Poincare maps), and is termed tech base phrases. These tech base phrases can be categorized two ways, depending on the taxonomy objectives. One way is to establish general tech base categories (e.g., stability, coupling, scaling, etc), and manually assign these tech base phrases to the appropriate general categories. The other way is to relate the tech base phrases to the more technology or application specific categories, based on the system-specific context in which they were used in the unstructured text. For the latter assignment of tech base phrases into application-specific categories, phrase proximity analysis is required.

For a system or technology-specific technical phrase (e.g., lasers), phrase proximity analysis generates a dictionary of phrases located in close physical proximity to the system-specific phrase throughout the text. Each phrase in the dictionary has a number of associated numerical indicators, including its frequency of occurrence throughout the text. These dictionary phrases are then assigned to the system-specific category in the taxonomy. Depending on the objectives of the study, tech base phrase duplication in categories may be allowed, or adjustments may have to be made across all categories to eliminate phrase duplication (multiple counting).

1B. Statistical Clustering

The statistical clustering approaches start with the phrase frequency and location information, then group phrases based on their co-occurrence frequencies and other important numerical indicators. In this paper, the statistical clustering has used two software packages in tandem. The phrase frequency and location information is generated by TechOasis, a software package from Search Technology. TechOasis uses Natural Language Processing (NLP) to extract the phrases and their frequencies from the free text. Not all phrases are extracted (typical of all NLP), and manual cleanup of the extracted phrases is still required to eliminate the lower technical content phrases. Also, unlike the multiple counting of nested phrases in TextDicer/ TextSlicer, multiple counting of nested phrases in TechOasis is disallowed (i.e., METAL MATRIX would be counted once as a double word phrase, but neither METAL nor MATRIX would be counted as single word phrases). The resulting phrase frequency and co-occurrence matrix information is then exported from TechOasis to WINSTAT, an excellent Excel add-in software package. Two types of output are generated by WINSTAT: factor matrix and multi-link clustering. Each of these processes will now be described.

1B-1. Multi-Link Clustering

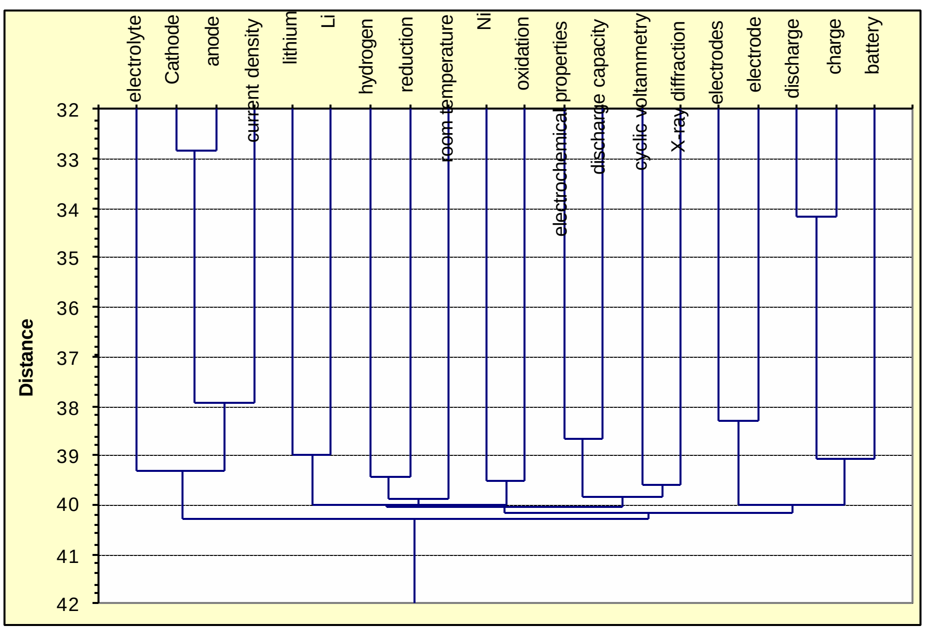
Phrase multi-link clustering starts with pre-defined metrics (variables), and groups phrases (cases) based on the strength of their relationships with these metrics. For

example, if a symmetric phrase-phrase matrix is used as the basis for clustering, then the closeness of two phrases (cases) will be determined by their co-occurrence profile with all other phrases (variables). The clustering becomes a co-occurrence profile matching process. The WINSTAT software package produces three types of related outputs.

1) A dendogram that shows the quantitative linkages among closely-related phrases. To provide a different perspective for the reader, an example is taken from a recent study on Electrochemical Power Sources text mining. Figure A1B-1, for example, is a dendogram that portrays linkages among the twenty highest frequency technical content phrases from the Electrochemical Abstracts database.

   A dendogram is a tree-like structure that shows linkages among phrases. It does so by starting with a root that encompasses all the phrases (See the vertical line on Figure A1B-1 ranging from a Distance value of 42 to slightly over 40). Then it splits into two groups (clusters) until all the phrases are contained in their own cluster. In Figure A1B-1, the root at the bottom of the page encompasses all the phrases. The first split is into two large clusters. One cluster contains the phrases ELECTROLYTE, CELL, CATHODE, ANODE, and CELLS. The second cluster contains all the remaining phrases LITHIUM, ELECTROCHEMICAL PROPERTIES, CYCLIC VOLTAMMETRY, X-RAY DIFFRACTION, ELECTRODES, ELECTRODE, HYDROGEN, ALLOY, ALLOYS, BATTERY, AIR, OXYGEN, OXIDATION, WATER, and CONDUCTIVITY. The clustering process can be continued at different hierarchical levels.

FIGURE A1B-1 – EXAMPLE TWENTY PHRASE DENDOGRAM



2) A table that contains a quantitative measure of the similarity of adjoining phrases or phrase-cluster pairs. The similarity, or 'distance', is obtained by matching the profiles as described above. Figure A1B-2, for example, is a table that contains the information portrayed in Figure A1B-1. The distances shown on the dendogram are taken from the distances given in this table; thus, the table is the numerical expression of the dendogram.

FIGURE A1B-2 – ELEMENTAL STEPS IN DENDOGRAM FORMATION

joining Cluster 1	**Size 1**	**with Cluster 2**	**Size 2**	**Distance**
Cathode	1	anode	1	32.83216927
discharge	1	charge	1	34.16843369
Cathode	2	current density	1	37.9232786
electrodes	1	electrode	1	38.29297045
electrochemical properties	1	discharge capacity	1	38.68748862
lithium	1	Li	1	39.00662295
discharge	2	battery	1	39.06016967
electrolyte	1	Cathode	3	39.33157288
hydrogen	1	reduction	1	39.42153664
Ni	1	oxidation	1	39.52735747
cyclic voltammetry	1	X-ray diffraction	1	39.58094847
electrochemical properties	2	cyclic voltammetry	2	39.85159646
hydrogen	2	room temperature	1	39.86541946
hydrogen	3	Ni	2	39.97396716
electrodes	2	discharge	3	39.97805457

lithium	2	hydrogen	5	40.00961352
lithium	7	electrochemical properties	4	40.04779843
lithium	11	electrodes	5	40.17291601
electrolyte	4	lithium	16	40.26135359

3) A taxonomy of a pre-specified number of groups of phrases. Figure A1B-3, for example, shows the groupings of phrases when four clusters were specified for the data portrayed in Figure A1B-1.

FIGURE A1B-3

Cluster #	**Phrases**
1	electrolyte
2	lithium
3	electrodes
3	electrode
2	Li
1	Cathode
2	hydrogen
2	room temperature
4	electrochemical properties
4	cyclic voltammetry
2	reduction
1	anode
3	discharge
4	X-ray diffraction
2	Ni
4	discharge capacity
3	battery
3	charge
2	oxidation
1	current density

Final categories can be generated two ways. The clusters can be manually grouped into categories. Or, the number of categories (clusters) can be specified to the algorithm, and the computer output will contain the final categories. Usually, some modest manual re-grouping of the computer output groups is required to arrive at a final recommended taxonomy.

1C. FACTOR MATRIX CLUSTERING

Factor matrix clustering generates a correlation matrix from the frequency and location information of the phrases. It then generates factors that are composed of all the phrases in the correlation matrix. The phrases are ordered quantitatively by their correlation with each other, with the most strongly correlated assigned the highest quantitative values.

Appendix 3 shows an author factor matrix. The grouping metric was the number of co-authored publications, taking into account the total number of publications of each author. In order to display all factors on one page width, the column widths had to be shrunk drastically. The matrix element values were hidden, but the shadings could be displayed, and they represent high correlation values (factor loadings). The darker the shading, the higher the value.

The number of factors generated can be fully discretionary (e.g., select a ten factor matrix, with no floor on the eigenvalues), or partially discretionary (e.g., set an eigenvalue floor of unity, let the algorithm generate the final number of factors). Final taxonomies can be generated by manually combining factors into categories, or specifying the number of categories (factors) desired to the algorithm.

The author factor matrix in Appendix 3 was generated by selecting an eigenvalue floor of unity. In practice, this means that each factor generated will add new information. Analysis of the author factor matrix in Appendix 3 is performed in the author bibliometrics section of the text, and will not be repeated here.

APPENDIX 2 – MARGINAL UTILITY ALGORITHM

The full 146 term query that was used to retrieve the SCI records for the final iteration (Q1) was:

((CHAO* AND (SYSTEM* OR DYNAMIC* OR PERIODIC* OR NONLINEAR OR NON-LINEAR OR BIFURCATION* OR MOTION* OR OSCILLAT* OR CONTROL* OR EQUATION* OR EXPONENT* OR FEEDBACK* OR LYAPUNOV OR MAP* OR ORBIT* OR ALGORITHM* OR HAMILTONIAN OR LIMIT* OR QUANTUM OR RANDOM OR REGIME* OR REGION* OR SERIES OR SIMULATION* OR THEORY OR AMPLITUDE* OR COMMUNICATION* OR COMPLEX* OR CONVECTION OR CORRELATION* OR COUPLING OR CYCLE* OR DEGREES OF FREEDOM OR DETERMINISTIC OR DIFFUSION OR DIMENSION* OR DISTRIBUTION* OR DUFFING OR ENTROPY OR EQUILIBRIUM OR FLUCTUATION* OR FRACTAL* OR

INITIAL CONDITION* OR INVARIANT* OR LASER* OR LOGISTIC OR LORENZ OR MAGNETIC FIELD* OR MECHANISM* OR MODES OR NETWORK* OR ONSET OR TIME OR FREQUENC* OR POPULATION* OR STABLE OR ADAPTIVE OR CIRCUIT* OR DISSIPAT* OR EVOLUTION OR EXPERIMENTAL OR GROWTH OR HARMONIC* OR HOMOCLINIC OR INSTABILIT* OR OPTICAL)) OR (BIFURCATION* AND (NONLINEAR OR HOMOCLINIC OR QUASIPERIODIC OR QUASI-PERIODIC OR DOUBLING OR DYNAMICAL SYSTEM* OR EVOLUTION OR INSTABILIT* OR SADDLE-NODE* OR MOTION* OR OSCILLAT* OR TRANSCRITICAL OR BISTABILITY OR LIMIT CYCLE* OR POINCARE OR LYAPUNOV OR ORBIT*)) OR (NONLINEAR AND (PERIODIC SOLUTION* OR OSCILLAT* OR MOTION* OR HOMOCLINIC)) OR (DYNAMICAL SYSTEM* AND (NONLINEAR OR STOCHASTIC OR NON-LINEAR)) OR ATTRACTOR* OR PERIOD DOUBLING* OR CORRELATION DIMENSION* OR LYAPUNOV EXPONENT* OR PERIODIC ORBIT* OR NONLINEAR DYNAMICAL) NOT (CHAO OR CHAOBOR* OR CHAOTROP* OR CAROTID OR ARTERY OR STENOSIS OR PULMONARY OR VASCULAR OR ANEURYSM* OR ARTERIES OR VEIN* OR TUMOR* OR SURGERY)

In the order presented, each of the terms preceding the NOT boolean was inserted into the Marginal Utility algorithm, and the following numerical indicators were obtained:

THEME	PHRASE	DeltaRel	CumRel	NormCumRel	Phrase #
CHAOTIC	SYSTEM	195	195	0.1480638	1
NONLINEAR	MOTION	157	352	0.2672741	2
CHAOTIC	SYSTEMS	89	441	0.3348519	3
CHAOTIC	DYNAMICS	61	502	0.3811693	4
BIFURCATION	NONLINEAR	58	560	0.4252088	5
CHAOS	SYSTEM	55	615	0.4669704	6
	ATTRACTOR	54	669	0.5079727	7
NONLINEAR	OSCILLATIONS	51	720	0.546697	8
NONLINEAR	OSCILLATION	32	752	0.5709947	9
DYNAMICAL SYSTEMS	NONLINEAR	29	781	0.5930144	10
NONLINEAR	MOTIONS	28	809	0.6142749	11
	ATTRACTORS	28	837	0.6355353	12
CHAOTIC	PERIODIC	26	863	0.6552771	13
NONLINEAR	OSCILLATOR	25	888	0.6742597	14
CHAOTIC	NONLINEAR	16	904	0.6864085	15
CHAOS	DYNAMICS	16	920	0.6985573	16
BIFURCATION	MOTION	16	936	0.7107062	17
	PERIODIC ORBIT	16	952	0.722855	18
	LYAPUNOV EXPONENT	15	967	0.7342445	19
	LYAPUNOV	14	981	0.7448747	20

	EXPONENTS				
CHAOS	SYSTEMS	13	994	0.7547456	21
BIFURCATIONS	NONLINEAR	12	1006	0.7638573	22
NONLINEAR	OSCILLATING	11	1017	0.7722096	23
NONLINEAR	PERIODIC SOLUTIONS	11	1028	0.7805619	24
DYNAMICAL SYSTEMS	STOCHASTIC	11	1039	0.7889142	25
DYNAMICAL SYSTEM	NONLINEAR	11	1050	0.7972665	26
CHAOTIC	MOTION	11	1061	0.8056188	27
BIFURCATION	INSTABILITY	11	1072	0.8139711	28
CHAOS	QUANTUM	10	1082	0.8215642	29
BIFURCATION	ORBITS	10	1092	0.8291572	30
	CORRELATION DIMENSION	10	1102	0.8367502	31
CHAOS	THEORY	9	1111	0.8435839	32
CHAOTIC	DISTRIBUTION	7	1118	0.848899	33
CHAOTIC	DIMENSION	7	1125	0.8542141	34
CHAOTIC	MAP	7	1132	0.8595292	35
BIFURCATION	EVOLUTION	7	1139	0.8648443	36
BIFURCATION	OSCILLATIONS	7	1146	0.8701595	37
DYNAMICAL SYSTEM	STOCHASTIC	6	1152	0.8747153	38
CHAOTIC	LYAPUNOV	6	1158	0.8792711	39
BIFURCATION	OSCILLATORY	6	1164	0.8838269	40
BIFURCATION	ORBIT	6	1170	0.8883827	41
	NONLINEAR DYNAMICS	6	1176	0.8929385	42
	NONLINEAR DYNAMICAL	6	1182	0.8974943	43
CHAOTIC	COUPLING	5	1187	0.9012908	44
CHAOTIC	SERIES	5	1192	0.9050873	45
CHAOTIC	EQUATIONS	5	1197	0.9088838	46
CHAOTIC	QUANTUM	5	1202	0.9126803	47
CHAOTIC	CONTROL	5	1207	0.9164768	48
BIFURCATION	LIMIT CYCLE	5	1212	0.9202733	49
DYNAMICAL SYSTEMS	NON-LINEAR	4	1216	0.9233106	50
CHAOTIC	FLUCTUATIONS	4	1220	0.9263478	51
CHAOTIC	OSCILLATIONS	4	1224	0.929385	52
CHAOTIC	THEORY	4	1228	0.9324222	53
CHAOTIC	COMPLEX	4	1232	0.9354594	54
BIFURCATIONS	INSTABILITIES	4	1236	0.9384966	55

BIFURCATION	BISTABILITY	4	1240	0.9415338	56
BIFURCATION	HOMOCLINIC	4	1244	0.944571	57
CHAOTIC	ALGORITHM	3	1247	0.9468489	58
CHAOTIC	SIMULATIONS	3	1250	0.9491268	59
CHAOTIC	REGION	3	1253	0.9514047	60
CHAOTIC	BIFURCATION	3	1256	0.9536826	61
CHAOS	NONLINEAR	3	1259	0.9559605	62
BIFURCATIONS	HOMOCLINIC	3	1262	0.9582384	63
BIFURCATION	SADDLE-NODE	3	1265	0.9605163	64
CHAOTIC	CONTROLLING	2	1267	0.9620349	65
CHAOTIC	FRACTAL	2	1269	0.9635535	66
CHAOTIC	EQUATION	2	1271	0.9650721	67
CHAOTIC	REGIONS	2	1273	0.9665907	68
CHAOTIC	FEEDBACK	2	1275	0.9681093	69
CHAOTIC	ORBITS	2	1277	0.9696279	70
CHAOS	ENTROPY	2	1279	0.9711465	71
CHAOS	CORRELATION	2	1281	0.9726651	72
CHAOS	DISTRIBUTION	2	1283	0.9741838	73
CHAOS	DIMENSION	2	1285	0.9757024	74
CHAOS	MAP	2	1287	0.977221	75
BIFURCATIONS	SADDLE-NODE	2	1289	0.9787396	76
BIFURCATIONS	ORBITS	2	1291	0.9802582	77
BIFURCATION	TRANSCRITICAL	2	1293	0.9817768	78
BIFURCATION	LIMIT CYCLES	2	1295	0.9832954	79
CHAOTIC	HAMILTONIAN	1	1296	0.9840547	80
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CHAOTIC	DYNAMIC	1	1299	0.9863326	83
CHAOTIC	COMMUNICATION	1	1300	0.9870919	84
CHAOS	SIMULATION	1	1301	0.9878512	85
CHAOS	DYNAMIC	1	1302	0.9886105	86
CHAOS	DETERMINISTIC	1	1303	0.9893698	87
CHAOS	BIFURCATION	1	1304	0.9901291	88
CHAOS	COMPLEX	1	1305	0.9908884	89
CHAOS	EQUATIONS	1	1306	0.9916477	90
CHAOS	LYAPUNOV	1	1307	0.992407	91
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BIFURCATIONS	BISTABILITY	1	1310	0.9946849	94
BIFURCATIONS	DOUBLING	1	1311	0.9954442	95
BIFURCATION	OSCILLATE	1	1312	0.9962035	96
BIFURCATION	INSTABILITIES	1	1313	0.9969628	97
BIFURCATION	POINCARE	1	1314	0.9977221	98
BIFURCATION	MOTIONS	1	1315	0.9984814	99

BIFURCATION	LYAPUNOV	1	1316	0.9992407	100
	PERIOD DOUBLING	1	1317	1	101
NONLINEAR	OSCILLATE	0	1317	1	102
CHAOTIC	COMMUNICATIONS	0	1317	1	103
CHAOTIC	FLUCTUATION	0	1317	1	104
CHAOTIC	CONTROLLER	0	1317	1	105
CHAOTIC	DISTRIBUTIONS	0	1317	1	106
CHAOTIC	NON-LINEAR	0	1317	1	107
CHAOTIC	OSCILLATORY	0	1317	1	108
CHAOTIC	ORBIT	0	1317	1	109
CHAOTIC	ENTROPY	0	1317	1	110
CHAOTIC	EXPONENTS	0	1317	1	111
CHAOTIC	EXPONENT	0	1317	1	112
CHAOTIC	DIFFUSION	0	1317	1	113
CHAOTIC	DETERMINISTIC	0	1317	1	114
CHAOTIC	AMPLITUDE	0	1317	1	115
CHAOTIC	BIFURCATIONS	0	1317	1	116
CHAOTIC	CORRELATION	0	1317	1	117
CHAOTIC	REGIME	0	1317	1	118
CHAOTIC	RANDOM	0	1317	1	119
CHAOTIC	SIMULATION	0	1317	1	120
CHAOS	FLUCTUATION	0	1317	1	121
CHAOS	COMPLEXES	0	1317	1	122
CHAOS	DEGREES OF FREEDOM	0	1317	1	123
CHAOS	COMPLEXITY	0	1317	1	124
CHAOS	REGIONS	0	1317	1	125
CHAOS	REGIMES	0	1317	1	126
CHAOS	EXPONENTS	0	1317	1	127
CHAOS	NON-LINEAR	0	1317	1	128
CHAOS	COMMUNICATION	0	1317	1	129
CHAOS	RANDOM	0	1317	1	130
CHAOS	REGIME	0	1317	1	131
CHAOS	SIMULATIONS	0	1317	1	132
CHAOS	BIFURCATIONS	0	1317	1	133
CHAOS	EXPONENT	0	1317	1	134
CHAOS	COUPLING	0	1317	1	135
CHAOS	SERIES	0	1317	1	136
CHAOS	FEEDBACK	0	1317	1	137
CHAOS	ORBITS	0	1317	1	138
CHAOS	OSCILLATIONS	0	1317	1	139
CHAOS	PERIODIC	0	1317	1	140

BIFURCATIONS	LIMIT CYCLES	0	1317	1	141
BIFURCATIONS	LIMIT CYCLE	0	1317	1	142
BIFURCATIONS	OSCILLATORY	0	1317	1	143
BIFURCATIONS	MOTION	0	1317	1	144
BIFURCATION	DOUBLING	0	1317	1	145
	PERIOD-DOUBLING	0	1317	1	146

When the query term is a phrase combination, the two columns on the left are the phrases in the combination, and when the query term is a single phrase, the second column from the left is the phrase. The third column from the left is the marginal increase in relevant records retrieved due to the addition of that query term, and the fourth column is the cumulative increase in relevant records. The fifth column represents the cumulative records retrieved divided by the total records retrieved by the full query. The sixth column is the phrase number; the un-truncated query contained 146 terms.

The results indicate a Pareto Law-type phenomenon: Retention of the top 25 query terms (~17%) retrieved about 79% of the records retrieved by the total query. Retention of the top 50 query terms retrieved about 92% of total records, and retention of the top 101 records retrieved 100% of the total. The top 101 terms were selected as the final query, although if query size had been more severely limited, an 80 term query could have been used with perhaps 1.5% less efficiency.

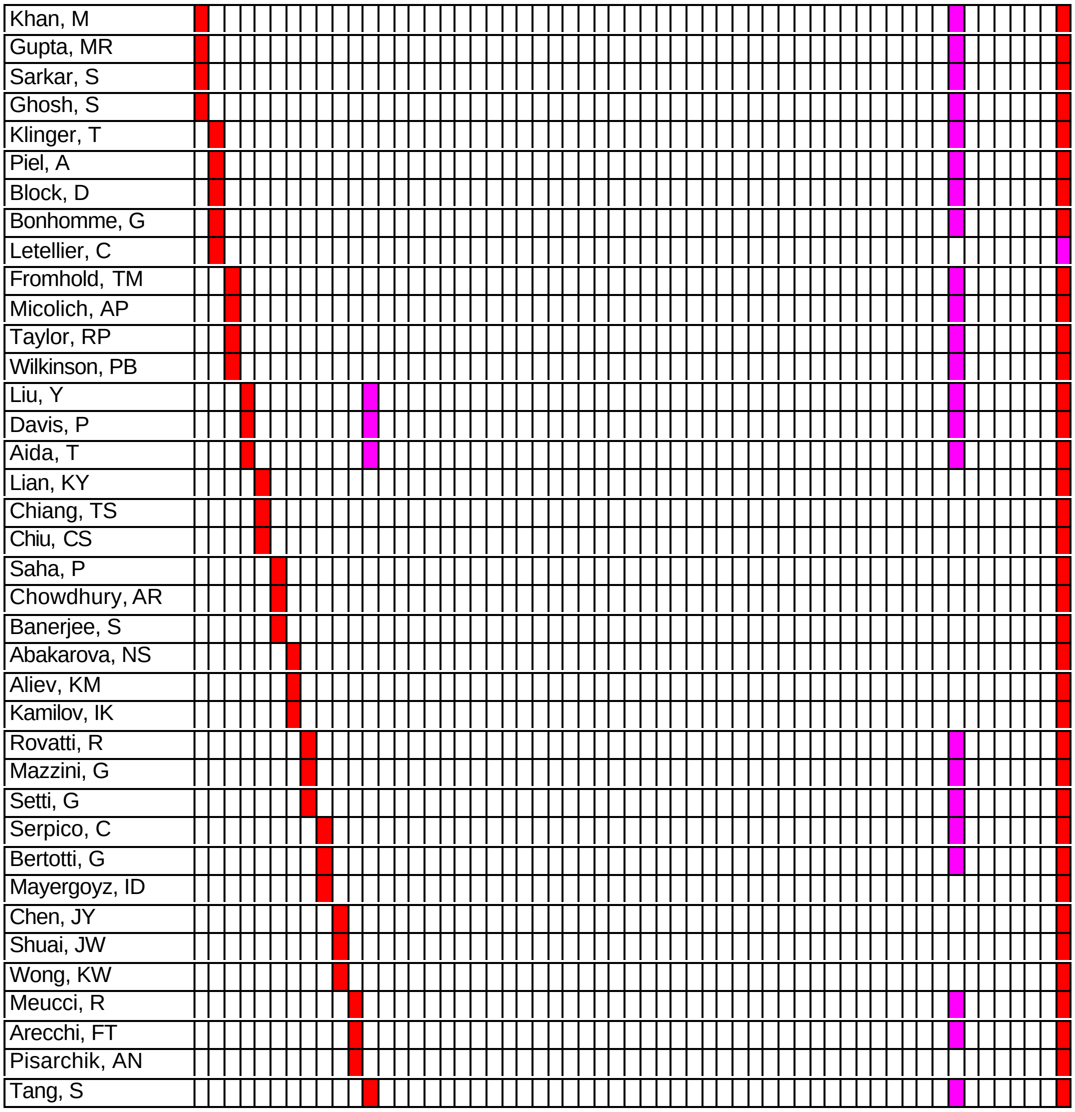
The final query used for the information processing (Q2) is the following:

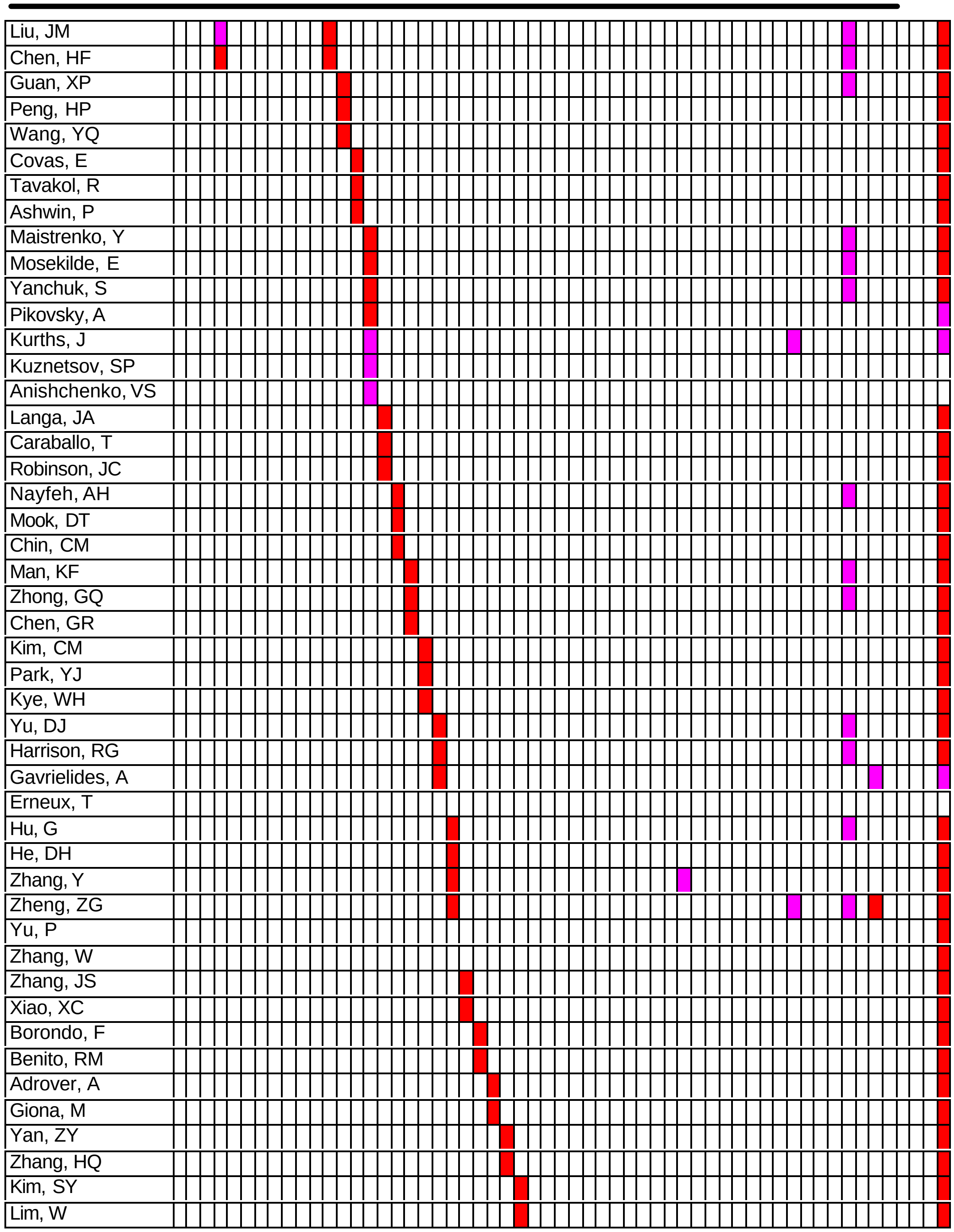
((CHAO* AND (SYSTEM* OR DYNAMIC* OR PERIODIC* OR NONLINEAR OR BIFURCATION* OR MOTION* OR OSCILLAT* OR CONTROL* OR EQUATION* OR FEEDBACK* OR LYAPUNOV OR MAP* OR ORBIT* OR ALGORITHM* OR HAMILTONIAN OR LIMIT* OR QUANTUM OR REGIME* OR REGION* OR SERIES OR SIMULATION* OR THEORY OR COMMUNICATION* OR COMPLEX* OR CONVECTION OR CORRELATION* OR COUPLING OR CYCLE* OR DETERMINISTIC OR DIMENSION* OR DISTRIBUTION* OR DUFFING OR ENTROPY OR EQUILIBRIUM OR FLUCTUATION* OR FRACTAL* OR INITIAL CONDITION* OR INVARIANT* OR LASER* OR LOGISTIC OR LORENZ OR MAGNETIC FIELD* OR MECHANISM* OR MODES OR NETWORK* OR ONSET OR TIME OR FREQUENC* OR POPULATION* OR STABLE OR ADAPTIVE OR CIRCUIT* OR DISSIPAT* OR EVOLUTION OR EXPERIMENTAL OR GROWTH OR HARMONIC* OR HOMOCLINIC OR INSTABILIT* OR OPTICAL)) OR (BIFURCATION* AND (NONLINEAR OR HOMOCLINIC OR QUASIPERIODIC OR QUASI-PERIODIC OR DOUBLING OR DYNAMICAL SYSTEM* OR EVOLUTION OR INSTABILIT* OR SADDLE-NODE* OR MOTION* OR OSCILLAT* OR TRANSCRITICAL OR BISTABILITY OR LIMIT CYCLE* OR POINCARE OR LYAPUNOV OR ORBIT*)) OR (NONLINEAR AND (PERIODIC SOLUTION* OR OSCILLAT* OR MOTION* OR HOMOCLINIC)) OR (DYNAMICAL SYSTEM* AND (NONLINEAR OR STOCHASTIC OR NON-LINEAR)) OR ATTRACTOR* OR PERIOD DOUBLING* OR CORRELATION DIMENSION* OR

LYAPUNOV EXPONENT* OR PERIODIC ORBIT* OR NONLINEAR DYNAMICAL) NOT (CHAO OR CHAOBOR* OR CHAOTROP* OR CAROTID OR ARTERY OR STENOSIS OR PULMONARY OR VASCULAR OR ANEURYSM* OR ARTERIES OR VEIN* OR TUMOR* OR SURGERY)

APPENDIX 3 – AUTHOR CLUSTERING DENDOGRAM

APPENDIX 3A – AUTHOR CLUSTERING FACTOR MATRIX

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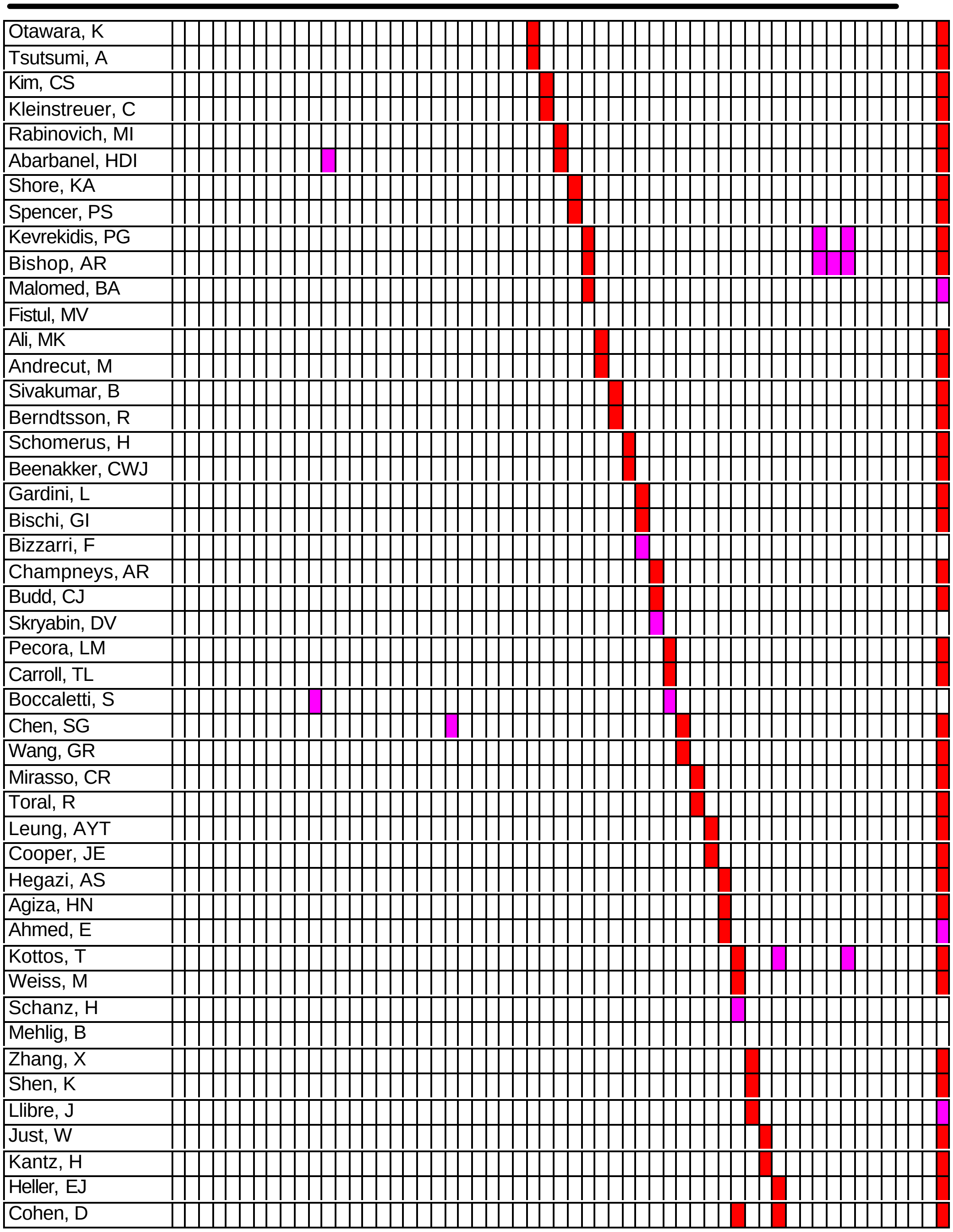
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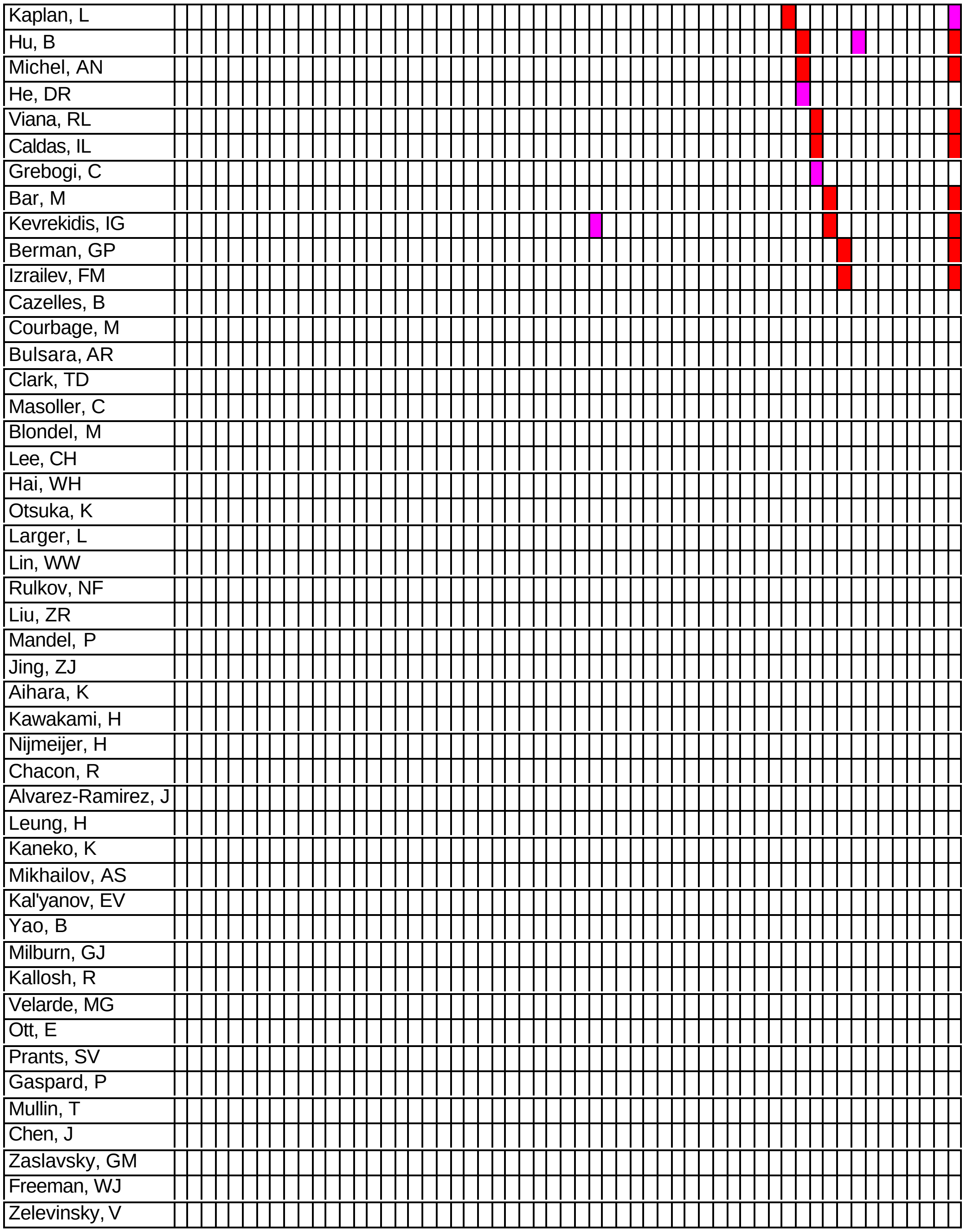
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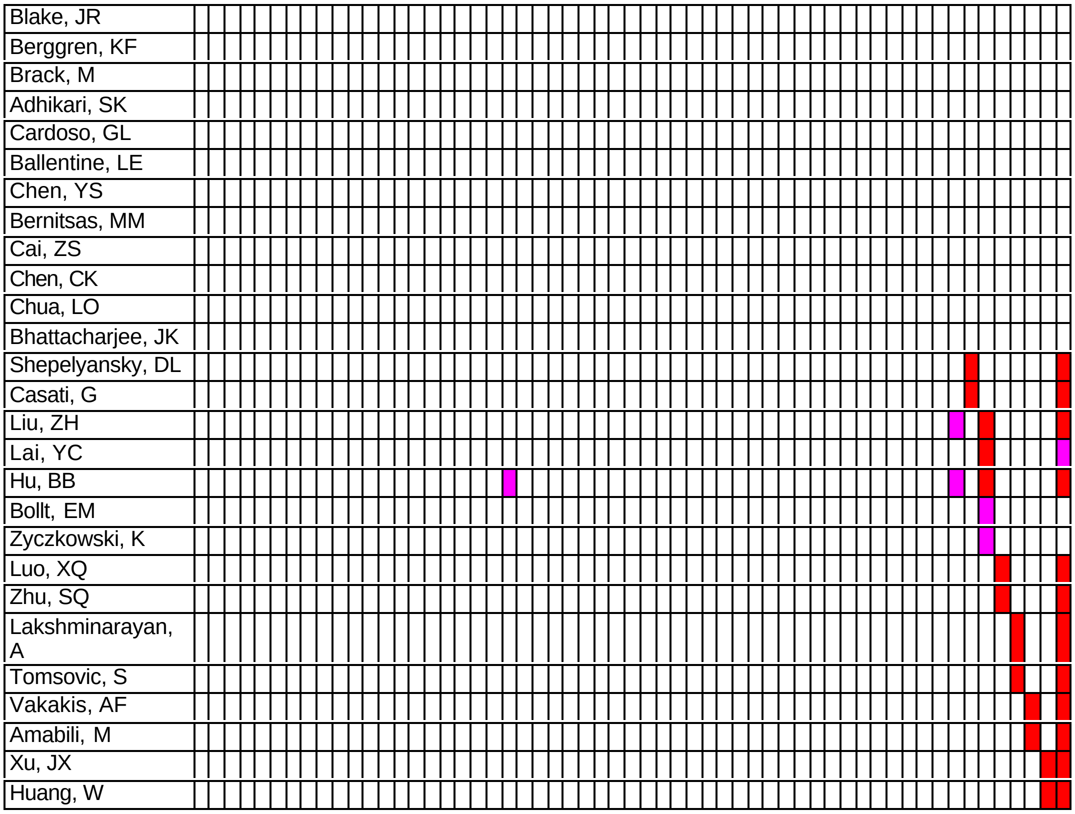
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Chua, LO
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Lai, YC
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Zyczkowski, K
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Zhu, SQ
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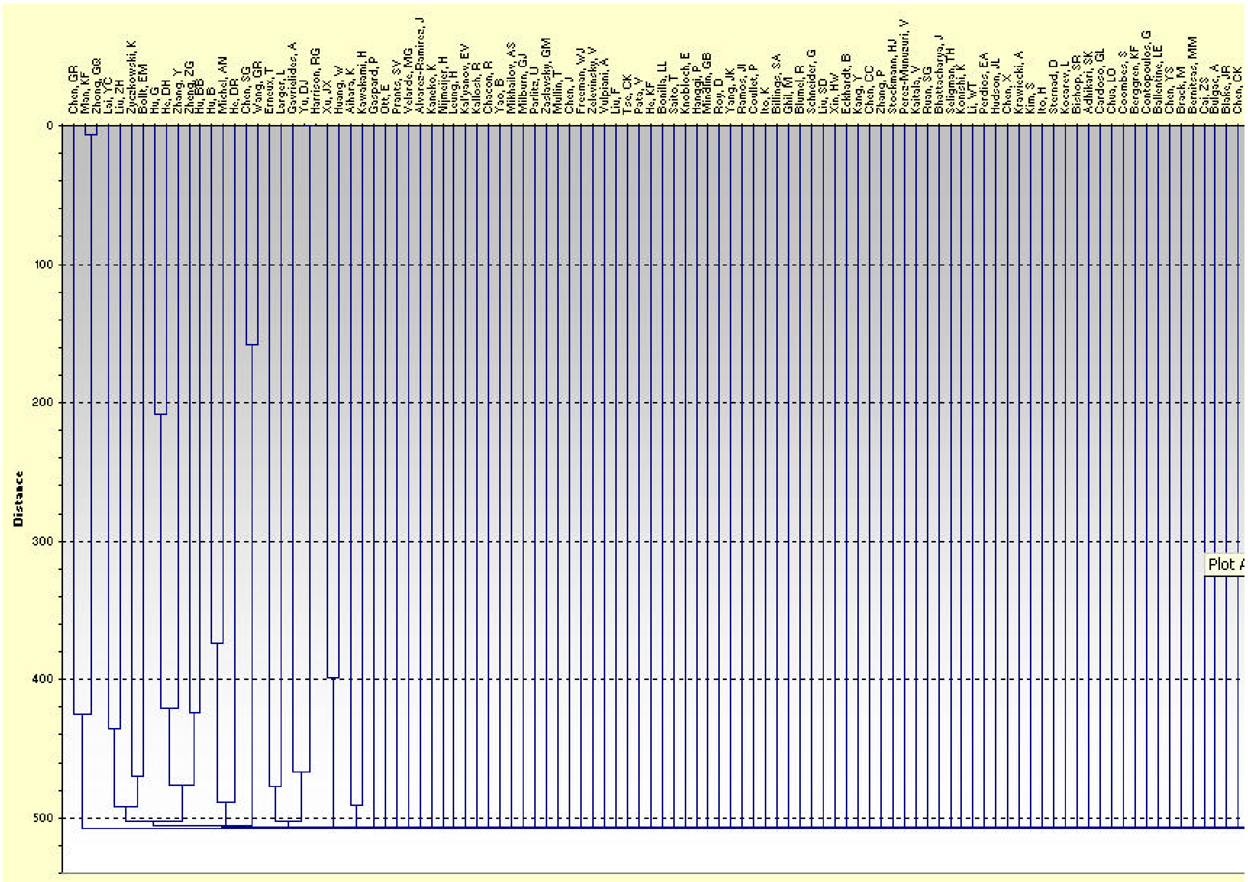
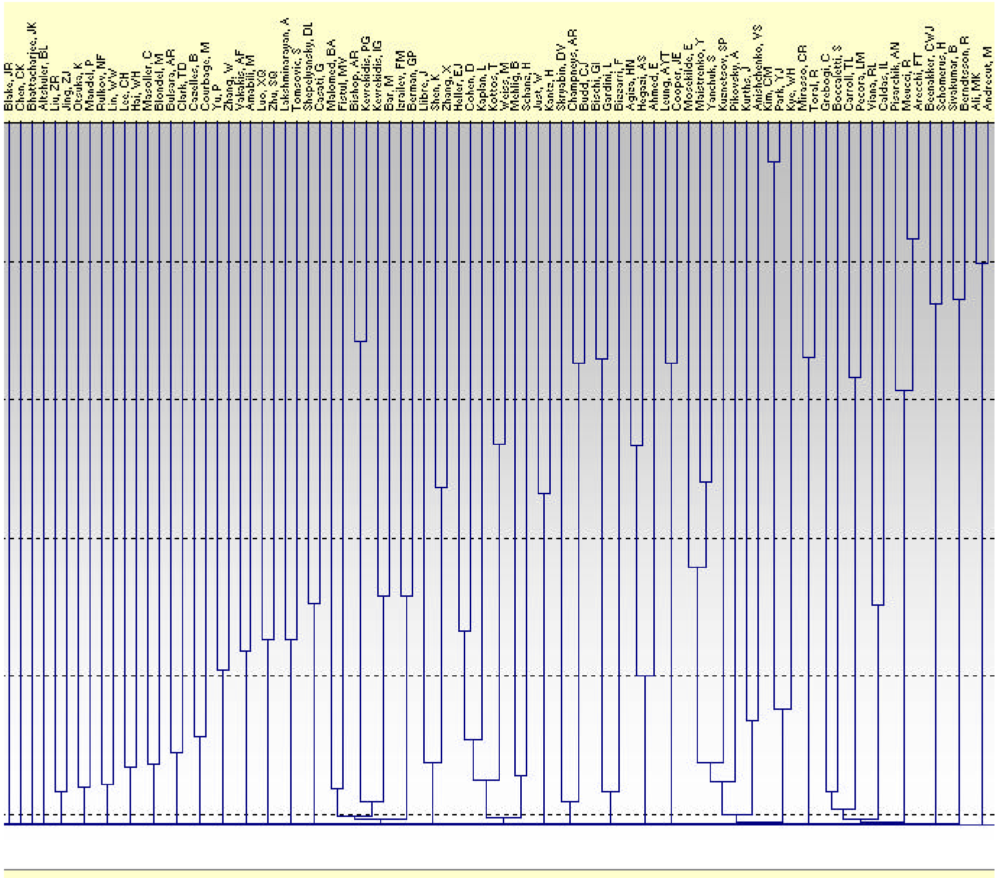
APPENDIX 3B – AUTHOR CLUSTERING DENDOGRAM





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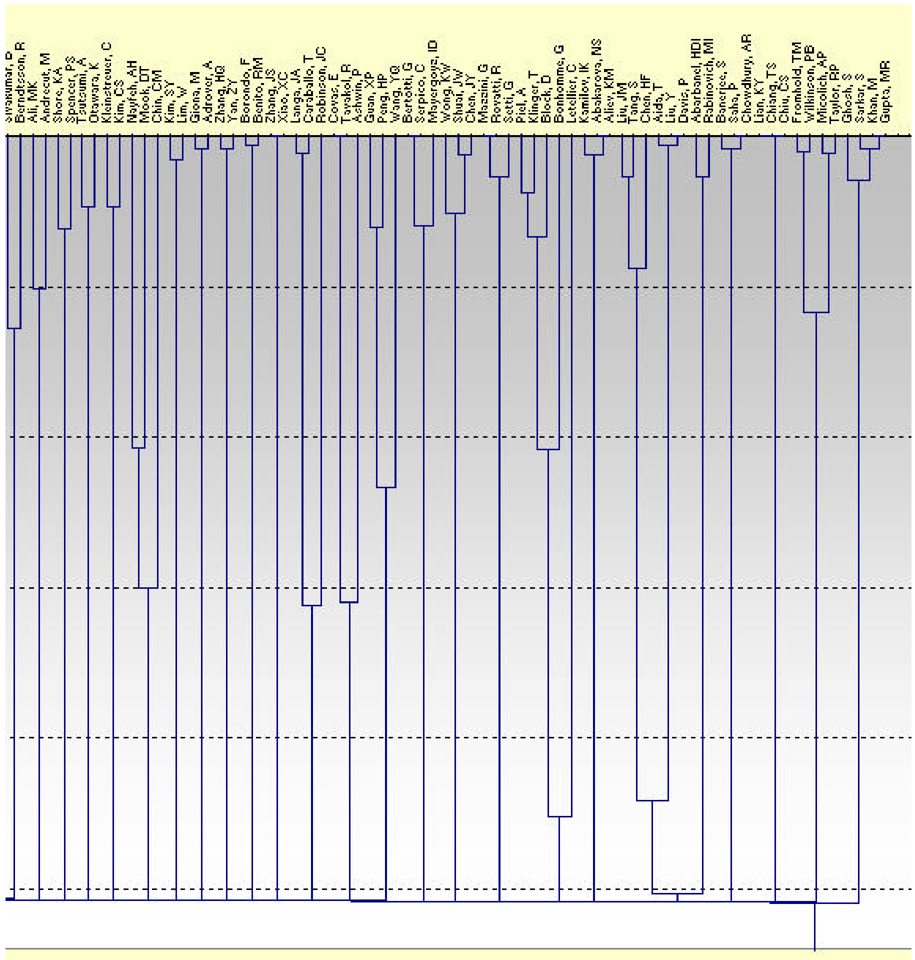
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Chiu, CS
Fromhold, TM
Wilkinson, PB
Micolich, AP
Taylor, RP
Ghosh, S
Sarkar, S
Khan, M
Gupta, MR

APPENDIX 4 – COUNTRY CO-PUBLISHING MATRIX

Items	Brazil	Canada	England	France	Germany	India	Israel	Italy	Japan	Netherlands	Peoples R China	Poland	Russia	Spain	USA
BRAZIL	173	0	4	10	5	0	1	4	0	1	6	1	3	4	29
CANADA	0	242	14	11	10	1	3	5	5	1	18	1	5	3	62
ENGLAND	4	14	415	20	28	4	5	9	5	12	10	4	19	11	55
FRANCE	10	11	20	426	28	4	3	27	8	7	0	4	21	11	62
GERMANY	5	10	28	28	585	3	19	18	8	21	13	16	44	12	74
INDIA	0	1	4	4	3	157	0	1	1	1	0	0	2	3	16
ISRAEL	1	3	5	3	19	0	127	1	4	2	0	4	4	2	37
ITALY	4	5	9	27	18	1	1	338	6	8	4	4	11	15	47
JAPAN	0	5	5	8	8	1	4	6	470	5	14	1	7	3	45
NETHERLANDS	1	1	12	7	21	1	2	8	5	141	1	1	12	6	27
PEOPLES R CHINA	6	18	10	0	13	0	0	4	14	1	588	0	3	5	72
POLAND	1	1	4	4	16	0	4	4	1	1	0	123	5	3	21
RUSSIA	3	5	19	21	44	2	4	11	7	12	3	5	394	13	26
SPAIN	4	3	11	11	12	3	2	15	3	6	5	3	13	260	39
USA	29	62	55	62	74	16	37	47	45	27	72	21	26	39	1797

APPENDIX 5 – KEYWORDS NON-STATISTICAL TAXONOMY

KEYWORD	FREQUENCY	CATEGORY	CUMULATIVE CATEGORY FREQUENCY
NEURAL NETWORKS	82	BRAIN	82
NEURONS	32	BRAIN	114
EEG	29	BRAIN	143
NEURAL NETWORK	21	BRAIN	164
ELECTROENCEPHALOGRAM	18	BRAIN	182
MEMORY	17	BRAIN	199
BRAIN	15	BRAIN	214
PERCEPTION	13	BRAIN	227
SLEEP	11	BRAIN	238
VISUAL-CORTEX	11	BRAIN	249
DEPRESSION	10	BRAIN	259
EPILEPSY	9	BRAIN	268
EPILEPTIC SEIZURES	9	BRAIN	277
CHAOS	841	CHAOS	841
CHAOTIC SYSTEMS	73	CHAOS	914

SPATIOTEMPORAL CHAOS	50	CHAOS	964
CHAOTIC SCATTERING	32	CHAOS	996
DETERMINISTIC CHAOS	15	CHAOS	1011
HYPERCHAOS	13	CHAOS	1024
CHAOTIC BEHAVIOR	12	CHAOS	1036
CHAOTIC ITINERANCY	11	CHAOS	1047
CLASSICAL CHAOS	9	CHAOS	1056
REACTION-DIFFUSION SYSTEMS	15	CHEMISTRY	15
ABSORPTION	14	CHEMISTRY	29
OXIDATION	12	CHEMISTRY	41
CHEMOSTAT	11	CHEMISTRY	52
ADSORPTION	10	CHEMISTRY	62
CO OXIDATION	10	CHEMISTRY	72
REACTION-DIFFUSION SYSTEM	10	CHEMISTRY	82
NETWORKS	44	CIRCUITS	44
CIRCUITS	31	CIRCUITS	75
CIRCUIT	15	CIRCUITS	90
NETWORK	12	CIRCUITS	102
HAMILTONIAN-SYSTEMS	42	CONSERVATION	42
FEEDBACK	54	CONTROL	54
CONTROLLING CHAOS	29	CONTROL	83
TRACKING	22	CONTROL	105
OPTICAL FEEDBACK	21	CONTROL	126
ADAPTIVE CONTROL	17	CONTROL	143
CONTROL	16	CONTROL	159
NONLINEAR CONTROL	14	CONTROL	173
CHAOS CONTROL	13	CONTROL	186
ADAPTIVE-CONTROL	12	CONTROL	198
MOTION CONTROL	9	CONTROL	207
ROBUST CONTROL	9	CONTROL	216
UNIVERSE	35	COSMOLOGY	35
CELESTIAL MECHANICS	16	COSMOLOGY	51
INFLATION	16	COSMOLOGY	67
CHAOTIC INFLATION	14	COSMOLOGY	81
STELLAR DYNAMICS	13	COSMOLOGY	94
COSMOLOGY	12	COSMOLOGY	106
BLACK-HOLES	11	COSMOLOGY	117
GALAXIES : KINEMATICS AND DYNAMICS	11	COSMOLOGY	128
ACCRETION	10	COSMOLOGY	138
SUN : MAGNETIC FIELDS	9	COSMOLOGY	147
DIMENSION	51	DIMENSIONALIT	51

		Y	
CORRELATION DIMENSION	43	DIMENSIONALIT Y	94
FRACTALS	24	DIMENSIONALIT Y	118
FRACTAL DIMENSION	20	DIMENSIONALIT Y	138
DIMENSIONS	16	DIMENSIONALIT Y	154
HAUSDORFF DIMENSION	13	DIMENSIONALIT Y	167
GENERALIZED DIMENSIONS	11	DIMENSIONALIT Y	178
FRACTAL	9	DIMENSIONALIT Y	187
PARAMETERS	9	DIMENSIONALIT Y	196
SELF-SIMILARITY	9	DIMENSIONALIT Y	205
HYSTERESIS	26	DISSIPATION	26
FRICTION	22	DISSIPATION	48
DISSIPATION	16	DISSIPATION	64
SHEAR	14	DISSIPATION	78
PATTERNS	53	ENTROPY	53
ENTROPY	43	ENTROPY	96
PATTERN-FORMATION	43	ENTROPY	139
ORGANIZATION	18	ENTROPY	157
DECOHERENCE	16	ENTROPY	173
COHERENCE	15	ENTROPY	188
PATTERN- FORMATION	15	ENTROPY	203
PATTERN FORMATION	14	ENTROPY	217
ORDER	12	ENTROPY	229
PATTERN	12	ENTROPY	241
CLUSTERS	11	ENTROPY	252
DISORDER	11	ENTROPY	263
DISORDERED-SYSTEMS	11	ENTROPY	274
COHERENT STRUCTURES	10	ENTROPY	284
EARTHQUAKE	15	ENVIRONMENT	15
GRAVITY	15	ENVIRONMENT	30
RAINFALL	15	ENVIRONMENT	45
EL-NINO	13	ENVIRONMENT	58
EARTHQUAKES	12	ENVIRONMENT	70
OCEAN	12	ENVIRONMENT	82
ATMOSPHERE	10	ENVIRONMENT	92

BIODIVERSITY	10	ENVIRONMENT	102
CALIFORNIA	10	ENVIRONMENT	112
ECOLOGY	10	ENVIRONMENT	122
SHALLOW-WATER	9	ENVIRONMENT	131
DYNAMICS	585	EVOLUTION	585
ATTRACTORS	166	EVOLUTION	751
MOTION	155	EVOLUTION	906
NONLINEAR DYNAMICS	142	EVOLUTION	1048
DYNAMICAL-SYSTEMS	105	EVOLUTION	1153
EVOLUTION	102	EVOLUTION	1255
STRANGE ATTRACTORS	97	EVOLUTION	1352
ATTRACTOR	42	EVOLUTION	1394
GROWTH	40	EVOLUTION	1434
CHAOTIC DYNAMICS	39	EVOLUTION	1473
DYNAMICAL SYSTEMS	38	EVOLUTION	1511
RELAXATION	33	EVOLUTION	1544
CONVERGENCE	29	EVOLUTION	1573
GLOBAL ATTRACTOR	26	EVOLUTION	1599
DECAY	19	EVOLUTION	1618
RIDDLED BASINS	19	EVOLUTION	1637
KINETICS	18	EVOLUTION	1655
POPULATION DYNAMICS	17	EVOLUTION	1672
TRAJECTORIES	17	EVOLUTION	1689
SYMBOLIC DYNAMICS	16	EVOLUTION	1705
POPULATION-DYNAMICS	15	EVOLUTION	1720
STRANGE ATTRACTOR	14	EVOLUTION	1734
BASINS	13	EVOLUTION	1747
CHAOTIC ATTRACTORS	13	EVOLUTION	1760
SEQUENCES	13	EVOLUTION	1773
COMPLEX DYNAMICS	12	EVOLUTION	1785
DYNAMICAL SYSTEM	12	EVOLUTION	1797
DYNAMICAL- SYSTEMS	12	EVOLUTION	1809
MOTIONS	12	EVOLUTION	1821
COMPLEX SPREADING SEQUENCES	11	EVOLUTION	1832
CHAOTIC DYNAMICAL-SYSTEMS	10	EVOLUTION	1842
DYNAMIC BEHAVIOR	10	EVOLUTION	1852
ASYMPTOTIC BEHAVIOR	9	EVOLUTION	1861
NONLINEAR DYNAMICAL SYSTEMS	9	EVOLUTION	1870
FIELD	69	EXPERIMENT	69
FIELDS	28	EXPERIMENT	97
MAGNETIC-FIELD	27	EXPERIMENT	124

SPECTROSCOPY	27	EXPERIMENT	151
SURROGATE DATA	19	EXPERIMENT	170
MAGNETIC-FIELDS	14	EXPERIMENT	184
PENDULUM	9	EXPERIMENT	193
TURBULENCE	111	FLUID FLOW	111
TRANSPORT	107	FLUID FLOW	218
FLOW	80	FLUID FLOW	298
DIFFUSION	78	FLUID FLOW	376
FLOWS	58	FLUID FLOW	434
CONVECTION	48	FLUID FLOW	482
FLUID	37	FLUID FLOW	519
GAS	27	FLUID FLOW	546
HYDRODYNAMICS	26	FLUID FLOW	572
VORTICES	26	FLUID FLOW	598
ANOMALOUS DIFFUSION	25	FLUID FLOW	623
FLUIDS	24	FLUID FLOW	647
WATER	22	FLUID FLOW	669
ADVECTION	19	FLUID FLOW	688
CHAOTIC ADVECTION	16	FLUID FLOW	704
CHAOTIC TRANSPORT	15	FLUID FLOW	719
RAYLEIGH-BENARD CONVECTION	15	FLUID FLOW	734
NAVIER-STOKES EQUATIONS	14	FLUID FLOW	748
CIRCULATION	13	FLUID FLOW	761
MHD	13	FLUID FLOW	774
LIQUID	11	FLUID FLOW	785
LIQUIDS	11	FLUID FLOW	796
TAYLOR-COUETTE FLOW	11	FLUID FLOW	807
SHEAR-FLOW	10	FLUID FLOW	817
VORTEX	10	FLUID FLOW	827
CHAOTIC FLOWS	9	FLUID FLOW	836
ELECTROCONVECTION	9	FLUID FLOW	845
SURFACE	39	GEOMETRY	39
LAYER	18	GEOMETRY	57
SURFACES	16	GEOMETRY	73
GEOMETRY	15	GEOMETRY	88
REGION	15	GEOMETRY	103
SHAPE	14	GEOMETRY	117
FILMS	11	GEOMETRY	128
CYLINDER	9	GEOMETRY	137
EDGE	9	GEOMETRY	146
ONSET	21	INITIALIZATION	21
SENSITIVITY	14	INITIALIZATION	35
INITIAL CONDITIONS	11	INITIALIZATION	46

LOCALIZATION	74	LOCALIZATION	74
WEAK-LOCALIZATION	14	LOCALIZATION	88
MAPS	47	MAPS	47
MAP	19	MAPS	66
MAPPINGS	16	MAPS	82
MANIFOLDS	12	MAPS	94
NORMAL FORMS	11	MAPS	105
LOGISTIC MAP	10	MAPS	115
DEFORMATION	19	MATERIALS	19
CONDUCTANCE	15	MATERIALS	34
DIODE	13	MATERIALS	47
CRYSTALS	11	MATERIALS	58
RHEOLOGY	11	MATERIALS	69
SEMICONDUCTORS	10	MATERIALS	79
BUCKLING	9	MATERIALS	88
MODEL	358	MODEL AND SIM	358
MODELS	108	MODEL AND SIM	466
EQUATIONS	106	MODEL AND SIM	572
EQUATION	65	MODEL AND SIM	637
SIMULATION	64	MODEL AND SIM	701
ALGORITHM	35	MODEL AND SIM	736
COMPUTATION	35	MODEL AND SIM	771
SIMULATIONS	24	MODEL AND SIM	795
APPROXIMATION	20	MODEL AND SIM	815
ALGORITHMS	18	MODEL AND SIM	833
MODELING	17	MODEL AND SIM	850
INTEGRATION	16	MODEL AND SIM	866
OPTIMIZATION	16	MODEL AND SIM	882
RECONSTRUCTION	15	MODEL AND SIM	897
METHODS : NUMERICAL	13	MODEL AND SIM	910
POTENTIALS	13	MODEL AND SIM	923
CELLULAR AUTOMATA	11	MODEL AND SIM	934
LINEARIZATION	11	MODEL AND SIM	945
OPERATORS	11	MODEL AND SIM	956
COEFFICIENTS	10	MODEL AND SIM	966
SHELL-MODEL	10	MODEL AND SIM	976
COMPUTER SIMULATION	9	MODEL AND SIM	985
FINITE ELEMENT METHOD	9	MODEL AND SIM	994
GENETIC ALGORITHMS	9	MODEL AND SIM	1003
NUMERICAL SIMULATION	9	MODEL AND SIM	1012
NOISE	102	NOISE	102
BROWNIAN-MOTION	14	NOISE	116
MULTIPLICATIVE NOISE	10	NOISE	126
BROWNIAN MOTION	9	NOISE	135

NOISE-REDUCTION	9	NOISE	144
SOLITONS	48	NONLINEAR	48
NONLINEARITY	41	NONLINEAR	89
NONLINEAR-SYSTEMS	40	NONLINEAR	129
NONLINEAR SYSTEMS	28	NONLINEAR	157
NONLINEAR	18	NONLINEAR	175
NON-LINEAR TRANSFORMATIONS	15	NONLINEAR	190
NONLINEAR ANALYSIS	13	NONLINEAR	203
SPATIAL SOLITONS	10	NONLINEAR	213
NONLINEAR SYSTEM	9	NONLINEAR	222
NONLINEAR OPTICS	29	OPTICS	29
LIGHT	28	OPTICS	57
CAVITY	27	OPTICS	84
LASER	24	OPTICS	108
LASERS	24	OPTICS	132
SEMICONDUCTOR-LASERS	23	OPTICS	155
CAVITIES	22	OPTICS	177
OPTICAL FIBERS	13	OPTICS	190
OPTICAL PARAMETRIC OSCILLATORS	13	OPTICS	203
BEAM	12	OPTICS	215
OPTICAL PARAMETRIC OSCILLATOR	11	OPTICS	226
OPTICS	11	OPTICS	237
BEAMS	9	OPTICS	246
FIBERS	9	OPTICS	255
OPTICAL COMMUNICATION	9	OPTICS	264
OPTICAL SOLITONS	9	OPTICS	273
OSCILLATIONS	165	OSCILLATIONS	165
OSCILLATORS	99	OSCILLATIONS	264
FLUCTUATIONS	74	OSCILLATIONS	338
OSCILLATION	51	OSCILLATIONS	389
OSCILLATOR	40	OSCILLATIONS	429
FREQUENCY	30	OSCILLATIONS	459
CYCLES	23	OSCILLATIONS	482
CHAOTIC OSCILLATORS	22	OSCILLATIONS	504
NONLINEAR OSCILLATIONS	19	OSCILLATIONS	523
VIBRATIONS	19	OSCILLATIONS	542
CONDUCTANCE FLUCTUATIONS	16	OSCILLATIONS	558
CYCLE	16	OSCILLATIONS	574
NONLINEAR OSCILLATORS	16	OSCILLATIONS	590
VIBRATION	16	OSCILLATIONS	606

COUPLED OSCILLATORS	14	OSCILLATIONS	620
LIMIT CYCLE	14	OSCILLATIONS	634
LIMIT CYCLES	13	OSCILLATIONS	647
LIMIT-CYCLES	13	OSCILLATIONS	660
KINETIC OSCILLATIONS	12	OSCILLATIONS	672
STARS : OSCILLATIONS	12	OSCILLATIONS	684
SOUTHERN OSCILLATION	9	OSCILLATIONS	693
PERIODIC-ORBITS	77	PERIODICITY	77
ORBITS	71	PERIODICITY	148
PERIODIC ORBITS	20	PERIODICITY	168
HOMOCLINIC ORBITS	19	PERIODICITY	187
PERIODIC SOLUTION	19	PERIODICITY	206
PERIODIC SOLUTIONS	19	PERIODICITY	225
PERIODIC-SOLUTIONS	14	PERIODICITY	239
PERIODIC ORBIT	11	PERIODICITY	250
PLASMA	22	PLASMA	22
PLASMAS	14	PLASMA	36
IONIZATION	12	PLASMA	48
TORUS	10	PLASMA	58
CONFINEMENT	9	PLASMA	67
MICROWAVE IONIZATION	9	PLASMA	76
QUANTUM CHAOS	74	QUANTUM	74
SCATTERING	50	QUANTUM	124
PARTICLES	32	QUANTUM	156
EXCITATION	28	QUANTUM	184
QUANTIZATION	27	QUANTUM	211
BILLIARDS	26	QUANTUM	237
QUANTUM	24	QUANTUM	261
LATTICES	21	QUANTUM	282
WAVE-FUNCTIONS	19	QUANTUM	301
EXCITATIONS	17	QUANTUM	318
ATOMS	16	QUANTUM	334
MOLECULAR-DYNAMICS	16	QUANTUM	350
NUCLEI	16	QUANTUM	366
ATOM	15	QUANTUM	381
COUPLED MAP LATTICES	15	QUANTUM	396
HYDROGEN-ATOM	12	QUANTUM	408
NONLINEAR LATTICES	12	QUANTUM	420
PARTICLE	12	QUANTUM	432
QUANTUM-MECHANICS	12	QUANTUM	444
DOTS	11	QUANTUM	455
BILLIARD	10	QUANTUM	465
SEMICLASSICAL QUANTIZATION	10	QUANTUM	475

ELECTRONS	9	QUANTUM	484
GROUND-STATE	9	QUANTUM	493
QUANTUM DOTS	9	QUANTUM	502
RYDBERG ATOMS	9	QUANTUM	511
SUPERLATTICES	9	QUANTUM	520
RESONANCE	50	RESONANCE	50
STOCHASTIC RESONANCE	48	RESONANCE	98
RESONANCES	37	RESONANCE	135
COHERENCE RESONANCE	14	RESONANCE	149
CELLS	26	SCALING	26
SCALE	12	SCALING	38
TIME-SERIES	117	SIGNALS	117
PROPAGATION	66	SIGNALS	183
INTERMITTENCY	51	SIGNALS	234
MODULATION	50	SIGNALS	284
SPECTRA	50	SIGNALS	334
COMMUNICATION	48	SIGNALS	382
SIGNALS	34	SIGNALS	416
ON-OFF INTERMITTENCY	32	SIGNALS	448
INFORMATION	28	SIGNALS	476
PULSES	27	SIGNALS	503
TRANSMISSION	18	SIGNALS	521
SIGNAL	17	SIGNALS	538
2ND-HARMONIC GENERATION	16	SIGNALS	554
CHAOTIC TIME-SERIES	15	SIGNALS	569
TIME-SERIES ANALYSIS	15	SIGNALS	584
POWER SPECTRUM	14	SIGNALS	598
AMPLIFICATION	11	SIGNALS	609
SECURE COMMUNICATIONS	11	SIGNALS	620
AMPLITUDE	10	SIGNALS	630
SERIES	10	SIGNALS	640
CRYPTOGRAPHY	9	SIGNALS	649
DELAY	9	SIGNALS	658
TIME-DELAY	9	SIGNALS	667
BOUNDARIES	17	SPATIAL BOUNDARY	17
INTERFACE	14	SPATIAL BOUNDARY	31
INTERFACES	13	SPATIAL BOUNDARY	44
BOUNDARY	12	SPATIAL BOUNDARY	56
STABILITY	310	STABILITY	310
BIFURCATION	191	STABILITY	501

INSTABILITY	139	STABILITY	640
BIFURCATIONS	135	STABILITY	775
TRANSITION	114	STABILITY	889
LYAPUNOV EXPONENTS	70	STABILITY	959
INSTABILITIES	62	STABILITY	1021
STABILIZATION	52	STABILITY	1073
HOPF BIFURCATION	36	STABILITY	1109
LYAPUNOV EXPONENT	31	STABILITY	1140
TRANSITIONS	26	STABILITY	1166
PHASE-TRANSITIONS	24	STABILITY	1190
EXPONENTS	23	STABILITY	1213
COLLAPSE	22	STABILITY	1235
BISTABILITY	17	STABILITY	1252
UNSTABLE PERIODIC-ORBITS	16	STABILITY	1268
SELF-ORGANIZED CRITICALITY	15	STABILITY	1283
STABILITY ANALYSIS	15	STABILITY	1298
TRANSVERSE INSTABILITY	15	STABILITY	1313
COHERENCE COLLAPSE	13	STABILITY	1326
HOPF-BIFURCATION	12	STABILITY	1338
NONLINEAR STABILITY	12	STABILITY	1350
GLOBAL BIFURCATIONS	10	STABILITY	1360
BIFURCATION ANALYSIS	9	STABILITY	1369
STOCHASTIC STABILITY	9	STABILITY	1378
STATES	83	STATES	83
EIGENFUNCTIONS	43	STATES	126
STATE	38	STATES	164
PHASE-SPACE	30	STATES	194
MODES	28	STATES	222
POINTS	20	STATES	242
MODE	19	STATES	261
SPACE	17	STATES	278
COHERENT STATES	11	STATES	289
STEADY-STATES	9	STATES	298
STATISTICS	56	STATISTICS	56
VARIABILITY	27	STATISTICS	83
SPECTRAL STATISTICS	21	STATISTICS	104
STATISTICAL-MECHANICS	16	STATISTICS	120
STATISTICAL PROPERTIES	12	STATISTICS	132
ENSEMBLES	10	STATISTICS	142
SYNCHRONIZATION	175	SYNCHRONIZATION	175
PHASE	49	SYNCHRONIZATION	224

PHASE SYNCHRONIZATION	45	SYNCHRONIZATION	269
GENERALIZED SYNCHRONIZATION	33	SYNCHRONIZATION	302
DRIVEN	27	SYNCHRONIZATION	329
LOCKING	24	SYNCHRONIZATION	353
CHAOS SYNCHRONIZATION	21	SYNCHRONIZATION	374
CHAOTIC SYNCHRONIZATION	13	SYNCHRONIZATION	387
DISCRETE BREATHERS	10	SYNCHRONIZATION	397
GINZBURG-LANDAU EQUATION	23	THEORY	23
CHAOS THEORY	22	THEORY	45
NONLINEAR SCHRODINGER-EQUATION	21	THEORY	66
DIFFERENTIAL-EQUATIONS	20	THEORY	86
SWIFT-HOHENBERG EQUATION	16	THEORY	102
THEOREM	15	THEORY	117
KURAMOTO-SIVASHINSKY EQUATION	14	THEORY	131
RANDOM-MATRIX THEORY	13	THEORY	144
LAW	12	THEORY	156
SEMICLASSICAL THEORY	12	THEORY	168
RANDOM MATRIX THEORY	11	THEORY	179
AMPLITUDE EQUATIONS	9	THEORY	188
DELAY DIFFERENTIAL EQUATION	9	THEORY	197
DIFFERENTIAL EQUATIONS	9	THEORY	206
PARTIAL-DIFFERENTIAL EQUATIONS	9	THEORY	215
ENERGY	28	THERMODYNAMIC	28
TEMPERATURE	20	THERMODYNAMICS	20
THERMODYNAMICS	17	THERMODYNAMICS	37
DENSITY	11	THERMODYNAMICS	48
PRESSURE	11	THERMODYNAMICS	59

WAVES	98	WAVES	98
SOLITARY WAVES	29	WAVES	127
TRAVELING WAVES	29	WAVES	156
FRONTS	17	WAVES	173
GRAVITY-WAVES	14	WAVES	187
SPIRAL WAVES	13	WAVES	200
SURFACE-WAVES	13	WAVES	213
WAVE	12	WAVES	225
WAVE-GUIDE ARRAYS	9	WAVES	234

APPENDIX 6A – ABSTRACT MANUAL TAXONOMY – MARGINAL UTILITY

TABLE A6A-1 – ABSTRACT TAXONOMY

ABSTRACT PHRASE	MARG FREQ	SUB-CATEGORY	SUB-FREQ
STRANGE ATTRACTOR	8	ATTRACTORS	8
STRANGE ATTRACTORS	7	ATTRACTORS	15
BASINS OF ATTRACTION	4	ATTRACTORS	19
POINT ATTRACTOR	11	ATTRACTORS	30
GLOBAL ATTRACTORS	8	ATTRACTORS	38
RIDDLED BASIN	9	ATTRACTORS	47
COEXISTING ATTRACTORS	7	ATTRACTORS	54
BASIN OF ATTRACTION	8	ATTRACTORS	62
GLOBAL ATTRACTOR	11	ATTRACTORS	73
CHAOTIC ATTRACTORS	4	ATTRACTORS	77
CHAOTIC ATTRACTOR	3	ATTRACTORS	80
ATTRACTION	4	ATTRACTORS	84
BASIN	4	ATTRACTORS	88
ATTRACTORS	10	ATTRACTORS	98
ATTRACTOR	6	ATTRACTORS	104
ORGANISMS	3	BIOLOGY	3
BIOLOGY	6	BIOLOGY	9
PROTEIN	5	BIOLOGY	14
GENETIC	3	BIOLOGY	17
NERVE	5	BIOLOGY	22
PROTEINS	8	BIOLOGY	30
ENZYME	3	BIOLOGY	33
BIOLOGICAL SYSTEMS	6	BIOLOGY	39
PLANKTON	5	BIOLOGY	44
MUSCLE	8	BIOLOGY	52
CIRCADIAN	3	BIOLOGY	55
DNA	3	BIOLOGY	58
BIOLOGICAL	4	BIOLOGY	62

EEG RECORDINGS	7	BRAIN	7
ARTIFICIAL NEURAL NETWORK	10	BRAIN	17
NEURON MODEL	4	BRAIN	21
SCHIZOPHRENIC	5	BRAIN	26
CEREBRAL	8	BRAIN	34
EPILEPSY	3	BRAIN	37
HIPPOCAMPAL	6	BRAIN	43
HIPPOCAMPUS	3	BRAIN	46
EPILEPTIC	1	BRAIN	47
CHAOTIC NEURAL NETWORK	9	BRAIN	56
REM SLEEP	4	BRAIN	60
SYNAPSES	7	BRAIN	67
CHAOTIC NEURAL	1	BRAIN	68
REM	0	BRAIN	68
SEIZURES	2	BRAIN	70
NEURAL NETWORK MODEL	4	BRAIN	74
SCHIZOPHRENIA	2	BRAIN	76
SEIZURE	1	BRAIN	77
CORTEX	5	BRAIN	82
CORTICAL	3	BRAIN	85
NEURONAL	4	BRAIN	89
SYNAPTIC	2	BRAIN	91
NEURON	4	BRAIN	95
NEURAL NETWORKS	7	BRAIN	102
BRAIN	1	BRAIN	103
SLEEP	1	BRAIN	104
EEG	1	BRAIN	105
NEURAL NETWORK	5	BRAIN	110
NEURONS	4	BRAIN	114
NEURAL	0	BRAIN	114
TRANSIENT CHAOS	10	CHAOS	10
CHAOTIC TRAJECTORIES	10	CHAOS	20
LAGRANGIAN CHAOS	6	CHAOS	26
NONLINEAR CHAOTIC	9	CHAOS	35
TRANSITION TO CHAOS	7	CHAOS	42
ROUTES TO CHAOS	9	CHAOS	51
DETERMINISTIC CHAOTIC	13	CHAOS	64
CHAOTIC REGIMES	12	CHAOS	76
ROBUST CHAOS	1	CHAOS	77
CHAOTIC SCATTERING	7	CHAOS	84
CLASSICALLY CHAOTIC	13	CHAOS	97
CHAOTICITY	13	CHAOS	110

CHAOTIC STATES	2	CHAOS	112
ONSET OF CHAOS	3	CHAOS	115
CHAOTIC STATE	5	CHAOS	120
ROUTE TO CHAOS	8	CHAOS	128
DETERMINISTIC CHAOS	6	CHAOS	134
CHAOTIC MOTIONS	4	CHAOS	138
CHAOTIC ORBITS	2	CHAOS	140
HYPERCHAOTIC	4	CHAOS	144
CHAOTIC REGIME	3	CHAOS	147
SPATIOTEMPORAL CHAOS	3	CHAOS	150
CHAOTIC SYSTEMS	7	CHAOS	157
CHAOS	18	CHAOS	175
CHAOTIC	21	CHAOS	196
SOLUTE	9	CHEMISTRY	9
REACTION-DIFFUSION EQUATIONS	10	CHEMISTRY	19
CO OXIDATION	9	CHEMISTRY	28
BELOUSOV-ZHABOTINSKY REACTION	11	CHEMISTRY	39
ANOMALOUS DIFFUSION	5	CHEMISTRY	44
REACTION RATE	9	CHEMISTRY	53
REACTANTS	6	CHEMISTRY	59
CAPACITORS	7	CHEMISTRY	66
CHEMISTRY	8	CHEMISTRY	74
RATE EQUATIONS	8	CHEMISTRY	82
CHEMICAL REACTION	9	CHEMISTRY	91
HEAT TRANSFER COEFFICIENT	1	CHEMISTRY	92
AUTOCATALYTIC	4	CHEMISTRY	96
DIFFUSION EQUATION	8	CHEMISTRY	104
BELOUSOV-ZHABOTINSKY	3	CHEMISTRY	107
ELECTROCHEMICAL	8	CHEMISTRY	115
ELECTRODE	4	CHEMISTRY	119
DIFFUSION COEFFICIENT	5	CHEMISTRY	124
CATALYTIC	5	CHEMISTRY	129
REACTION-DIFFUSION	4	CHEMISTRY	133
REACTIONS	9	CHEMISTRY	142
ELECTRONIC CIRCUIT	10	CIRCUITS	10
JOSEPHSON JUNCTION	7	CIRCUITS	17
JOSEPHSON JUNCTIONS	5	CIRCUITS	22
SWITCHES	7	CIRCUITS	29
ON-OFF INTERMITTENCY	3	CIRCUITS	32
CIRCUITS	11	CIRCUITS	43
CIRCUIT	3	CIRCUITS	46

DECODING	2	CODE	2
CODING	6	CODE	8
SECURITY	6	CODE	14
ENCRYPTION	2	CODE	16
PROPULSION	6	COMBUSTION	6
COMBUSTION	5	COMBUSTION	11
DETONATION	1	COMBUSTION	12
FLAME	2	COMBUSTION	14
FIRE	5	COMBUSTION	19
CHAOTIC COMMUNICATION	3	COMMUNICATION	3
COMMUNICATION SYSTEM	4	COMMUNICATION	7
COMMUNICATION SYSTEMS	1	COMMUNICATION	8
RADAR	2	COMMUNICATION	10
SECURE COMMUNICATION	2	COMMUNICATION	12
CHAOTIC COMMUNICATIONS	6	COMMUNICATION	18
FEEDBACKS	5	CONTROL	5
CONTROLLING CHAOS	8	CONTROL	13
BACKPROPAGATION	7	CONTROL	20
POSITIVE FEEDBACK	8	CONTROL	28
NEGATIVE FEEDBACK	9	CONTROL	37
CONTROL ALGORITHMS	6	CONTROL	43
BIFURCATION CONTROL	8	CONTROL	51
CONTROLLER DESIGN	12	CONTROL	63
FEEDBACK CONTROLLER	6	CONTROL	69
CONTROL THEORY	7	CONTROL	76
NONLINEAR FEEDBACK	9	CONTROL	85
ACTIVE CONTROL	9	CONTROL	94
CONTROL DESIGN	6	CONTROL	100
STATE FEEDBACK	5	CONTROL	105
TRACKING CONTROL	6	CONTROL	111
FEEDBACK LOOP	4	CONTROL	115
CONTROL ALGORITHM	5	CONTROL	120
MOTION CONTROL	10	CONTROL	130
CONTROLLABILITY	9	CONTROL	139
FEEDFORWARD	7	CONTROL	146
ROBUST CONTROL	3	CONTROL	149
CHAOS CONTROL	7	CONTROL	156
CONTROL STRATEGY	4	CONTROL	160
PROPOSED CONTROL	5	CONTROL	165
CONTROL LAWS	3	CONTROL	168
NONLINEAR CONTROL	6	CONTROL	174
DELAYED FEEDBACK	4	CONTROL	178
CONTROL SYSTEMS	7	CONTROL	185

CONTROL PROBLEM	4	CONTROL	189
CONTROL METHOD	6	CONTROL	195
CONTROL PARAMETERS	1	CONTROL	196
OPTICAL FEEDBACK	2	CONTROL	198
ADAPTIVE CONTROL	2	CONTROL	200
OPTIMAL CONTROL	5	CONTROL	205
CONTROL SCHEME	3	CONTROL	208
CONTROL LAW	3	CONTROL	211
CONTROLLERS	2	CONTROL	213
CONTROL SYSTEM	3	CONTROL	216
CONTROL PARAMETER	2	CONTROL	218
CONTROLS	3	CONTROL	221
FEEDBACK CONTROL	2	CONTROL	223
CONTROLLING	4	CONTROL	227
CONTROLLED	6	CONTROL	233
CONTROLLER	1	CONTROL	234
CONTROL	5	CONTROL	239
FEEDBACK	1	CONTROL	240
RELATIVITY	9	COSMOLOGY	9
NEW INFLATION	3	COSMOLOGY	12
INTERSTELLAR	9	COSMOLOGY	21
DARK MATTER	5	COSMOLOGY	26
COMET	4	COSMOLOGY	30
SOLAR WIND	5	COSMOLOGY	35
CORONAL	5	COSMOLOGY	40
DUSTY PLASMA	11	COSMOLOGY	51
MARS	4	COSMOLOGY	55
CRATERS	2	COSMOLOGY	57
SOLAR SYSTEM	9	COSMOLOGY	66
PLANETS	1	COSMOLOGY	67
SUNSPOT	7	COSMOLOGY	74
ASTEROID	2	COSMOLOGY	76
JUPITER	1	COSMOLOGY	77
BLACK HOLES	9	COSMOLOGY	86
INFLATON	7	COSMOLOGY	93
INFLATIONARY	7	COSMOLOGY	100
SUPERGRAVITY	7	COSMOLOGY	107
CHAOTIC INFLATION	7	COSMOLOGY	114
SATELLITES	2	COSMOLOGY	116
COSMOLOGY	5	COSMOLOGY	121
GALACTIC	10	COSMOLOGY	131
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QUASI-PERIODIC	2	PERIODICITY	143
QUASIPERIODIC	2	PERIODICITY	145
PERIOD-DOUBLING	2	PERIODICITY	147
PERIODIC ORBIT	14	PERIODICITY	161
PERIODIC ORBITS	12	PERIODICITY	173
PERIODIC	3	PERIODICITY	176
PHYS PLASMAS	8	PLASMA	8
TOKAMAK	9	PLASMA	17
PLASMA	2	PLASMA	19
PLASMAS	3	PLASMA	22
POPULATION GROWTH	4	POPULATION	4
PREDATOR-PREY	5	POPULATION	9
PREDATORS	6	POPULATION	15
INTRAMOLECULAR	9	QUANTUM	9
CHARGED PARTICLE	7	QUANTUM	16
QUANTUM-MECHANICAL	9	QUANTUM	25
ION MOTION	4	QUANTUM	29
QUANTUM INTERFERENCE	9	QUANTUM	38
COUPLED NONLINEAR SCHRODINGER	2	QUANTUM	40
CHAOTIC QUANTUM	11	QUANTUM	51
EXCITATION ENERGY	7	QUANTUM	58
QUANTUM CHAOTIC	11	QUANTUM	69
QUANTUM COMPUTER	7	QUANTUM	76
PROTON	6	QUANTUM	82
SCHRODINGER EQUATIONS	1	QUANTUM	83
COUPLED MAP LATTICES	6	QUANTUM	89
PROBABILITY DENSITY FUNCTION	7	QUANTUM	96
QUANTUM DYNAMICS	7	QUANTUM	103
COUPLED MAP LATTICE	2	QUANTUM	105
SUPERLATTICE	3	QUANTUM	108
MOLECULAR DYNAMICS	10	QUANTUM	118
WAVE EQUATION	11	QUANTUM	129
QUANTUM SYSTEM	8	QUANTUM	137
QUANTUM MECHANICS	12	QUANTUM	149

QUANTUM STATES	4	QUANTUM	153
SUPERLATTICES	5	QUANTUM	158
MOLECULE	3	QUANTUM	161
QUANTUM DOTS	9	QUANTUM	170
QUANTUM SYSTEMS	6	QUANTUM	176
QUANTUM MECHANICAL	9	QUANTUM	185
QUANTUM DOT	3	QUANTUM	188
WAVE FUNCTION	4	QUANTUM	192
NUCLEUS	3	QUANTUM	195
NUCLEI	8	QUANTUM	203
GROUND STATE	8	QUANTUM	211
PROBABILITY DENSITY	3	QUANTUM	214
IONS	1	QUANTUM	215
BILLIARDS	11	QUANTUM	226
MOLECULES	7	QUANTUM	233
SCHRODINGER EQUATION	3	QUANTUM	236
QUANTUM CHAOS	7	QUANTUM	243
BILLIARD	7	QUANTUM	250
ELECTRONS	5	QUANTUM	255
ION	6	QUANTUM	261
ATOMS	3	QUANTUM	264
ELECTRON	2	QUANTUM	266
QUANTUM	7	QUANTUM	273
RESONANT FREQUENCY	10	RESONANCE	10
NONLINEAR RESONANCE	11	RESONANCE	21
RESONANCE FREQUENCY	7	RESONANCE	28
RESONATORS	4	RESONANCE	32
COHERENCE RESONANCE	1	RESONANCE	33
PARAMETRIC RESONANCE	7	RESONANCE	40
INTERNAL RESONANCE	7	RESONANCE	47
RESONATOR	8	RESONANCE	55
STOCHASTIC RESONANCE	0	RESONANCE	55
RESONANT	5	RESONANCE	60
RESONANCE	3	RESONANCE	63
SELF-SIMILARITY	10	SCALING	10
TIME-SCALE	9	SCALING	19
SCALING PROPERTIES	10	SCALING	29
SCALING LAW	7	SCALING	36
FRACTAL DIMENSIONS	8	SCALING	44
LENGTH SCALES	3	SCALING	47
TIMESCALES	6	SCALING	53
SCALING LAWS	8	SCALING	61
SCALING BEHAVIOR	5	SCALING	66
LENGTH SCALE	3	SCALING	69

FRACTAL STRUCTURE	6	SCALING	75
FRACTALS	4	SCALING	79
SCALED	5	SCALING	84
TIMESCALE	4	SCALING	88
SMALL-SCALE	4	SCALING	92
MULTIPLE SCALES	5	SCALING	97
MULTIFRACTAL	5	SCALING	102
SELF-SIMILAR	4	SCALING	106
FRACTAL DIMENSION	5	SCALING	111
TIME SCALE	4	SCALING	115
TIME SCALES	2	SCALING	117
LARGE-SCALE	2	SCALING	119
SCALING	3	SCALING	122
SCALES	3	SCALING	125
FRACTAL	3	SCALING	128
SCALE	2	SCALING	130
VOLTERRA SERIES	7	SIGNALS	7
SUBHARMONICS	9	SIGNALS	16
SPREAD SPECTRUM	7	SIGNALS	23
SECOND HARMONIC GENERATION	11	SIGNALS	34
NONLINEAR TIME SERIES	10	SIGNALS	44
INPUT SIGNALS	5	SIGNALS	49
OUTPUT SIGNAL	11	SIGNALS	60
SECOND-HARMONIC	6	SIGNALS	66
INFORMATION SIGNAL	9	SIGNALS	75
SIGNAL PROCESSING	7	SIGNALS	82
CHAOTIC SIGNAL	2	SIGNALS	84
KALMAN FILTER	3	SIGNALS	87
MUTUAL INFORMATION	6	SIGNALS	93
INFORMATION PROCESSING	7	SIGNALS	100
TIME SERIES ANALYSIS	4	SIGNALS	104
RADIO	6	SIGNALS	110
TIME-SERIES	6	SIGNALS	116
SECOND HARMONIC	5	SIGNALS	121
ANHARMONIC	5	SIGNALS	126
CHAOTIC TIME SERIES	6	SIGNALS	132
CHAOTIC SIGNALS	3	SIGNALS	135
SUBHARMONIC	4	SIGNALS	139
COMMUNICATIONS	1	SIGNALS	140
HARMONICS	1	SIGNALS	141
COMMUNICATION	8	SIGNALS	149
HARMONIC	7	SIGNALS	156

SIGNALS	2	SIGNALS	158
TIME SERIES	6	SIGNALS	164
SIGNAL	3	SIGNALS	167
MICROCHIP	8	SOLID STATE	8
SOLID-STATE	6	SOLID STATE	14
GAAS	9	SOLID STATE	23
DIODES	3	SOLID STATE	26
SILICON	12	SOLID STATE	38
TUNNELLING	4	SOLID STATE	42
DIODE	3	SOLID STATE	45
DIELECTRIC	5	SOLID STATE	50
TUNNELING	6	SOLID STATE	56
SEMICONDUCTOR	2	SOLID STATE	58
BOUNDARY	1	SPATIAL BOUNDARY	1
BOUNDARY VALUE PROBLEMS	10	SPATIAL BOUNDARY	11
BOUNDARY CONDITION	8	SPATIAL BOUNDARY	19
FREE SURFACE	6	SPATIAL BOUNDARY	25
FREE BOUNDARY	6	SPATIAL BOUNDARY	31
DOMAIN WALLS	1	SPATIAL BOUNDARY	32
BOUNDARY VALUE PROBLEM	6	SPATIAL BOUNDARY	38
DOMAIN WALL	5	SPATIAL BOUNDARY	43
PERIODIC BOUNDARY CONDITIONS	2	SPATIAL BOUNDARY	45
NEUMANN	6	SPATIAL BOUNDARY	51
DIRICHLET	4	SPATIAL BOUNDARY	55
PERIODIC BOUNDARY	0	SPATIAL BOUNDARY	55
BOUNDARY VALUE	1	SPATIAL BOUNDARY	56
BOUNDARY CONDITIONS	3	SPATIAL BOUNDARY	59
BIFURCATION	2	STABILITY	2
BIFURCATIONS	3	STABILITY	5
VOLTAGE STABILITY	6	STABILITY	11
TRANSIENT STABILITY	4	STABILITY	15
STABLE EQUILIBRIUM	9	STABILITY	24
STABILITY THEORY	9	STABILITY	33
STABILITY REGION	6	STABILITY	39
STABILITY CRITERION	11	STABILITY	50
PERIOD DOUBLING BIFURCATION	5	STABILITY	55
MAXIMAL LYAPUNOV EXPONENT	10	STABILITY	65
LYAPUNOV CHARACTERISTIC	7	STABILITY	72

LIAPUNOV	7	STABILITY	79
DYNAMIC STABILITY	8	STABILITY	87
DOUBLING BIFURCATIONS	4	STABILITY	91
UNSTABLE PERIODIC ORBIT	10	STABILITY	101
STABLE STATES	9	STABILITY	110
STABLE LIMIT	10	STABILITY	120
SLOW MANIFOLD	5	STABILITY	125
EXPONENTIALLY STABLE	9	STABILITY	134
LOCAL BIFURCATION	7	STABILITY	141
HOMOCLINIC BIFURCATIONS	8	STABILITY	149
PITCHFORK BIFURCATIONS	7	STABILITY	156
MAXIMUM LYAPUNOV	8	STABILITY	164
STABILITY CONDITIONS	9	STABILITY	173
DESTABILIZATION	5	STABILITY	178
GLOBAL STABILITY	4	STABILITY	182
MAXIMAL LYAPUNOV	2	STABILITY	184
STABILIZES	9	STABILITY	193
STABILITIES	10	STABILITY	203
BIFURCATION STRUCTURE	10	STABILITY	213
INSTABILITY THRESHOLD	4	STABILITY	217
STABILITY BOUNDARIES	5	STABILITY	222
UNSTABLE MANIFOLDS	9	STABILITY	231
STABILITY AND BIFURCATION	4	STABILITY	235
LOSS OF STABILITY	6	STABILITY	241
BIFURCATION CURVES	7	STABILITY	248
LYAPUNOV SPECTRUM	8	STABILITY	256
PERIOD-DOUBLING BIFURCATIONS	7	STABILITY	263
DOUBLING BIFURCATION	1	STABILITY	264
POSITIVE LYAPUNOV EXPONENTS	11	STABILITY	275
UNSTABLE MODES	3	STABILITY	278
BIFURCATION PHENOMENA	6	STABILITY	284
EQUILIBRIUM POINTS	3	STABILITY	287
MULTISTABILITY	9	STABILITY	296
BIFURCATE	8	STABILITY	304
SADDLE-NODE BIFURCATIONS	7	STABILITY	311
ASYMPTOTICALLY STABLE	4	STABILITY	315
LOCAL STABILITY	4	STABILITY	319
HOMOCLINIC BIFURCATION	3	STABILITY	322
GLOBAL BIFURCATION	5	STABILITY	327

SADDLE-NODE BIFURCATION	3	STABILITY	330
EQUILIBRIUM POINT	7	STABILITY	337
LYAPUNOV FUNCTION	10	STABILITY	347
GLOBAL BIFURCATIONS	2	STABILITY	349
POSITIVE LYAPUNOV	2	STABILITY	351
DESTABILIZING	4	STABILITY	355
METASTABLE	8	STABILITY	363
STABLE PERIODIC	3	STABILITY	366
STABILITY PROPERTIES	5	STABILITY	371
BIFURCATING	4	STABILITY	375
CRITICAL POINTS	9	STABILITY	384
NONLINEAR STABILITY	8	STABILITY	392
BIFURCATION PARAMETER	1	STABILITY	393
ASYMPTOTIC STABILITY	5	STABILITY	398
PERIOD-DOUBLING BIFURCATION	3	STABILITY	401
BIFURCATION THEORY	7	STABILITY	408
STABILIZED	5	STABILITY	413
STABLE AND UNSTABLE	3	STABILITY	416
HOPF BIFURCATIONS	2	STABILITY	418
PITCHFORK BIFURCATION	3	STABILITY	421
STABILIZE	7	STABILITY	428
BIFURCATION POINTS	6	STABILITY	434
LINEAR STABILITY ANALYSIS	3	STABILITY	437
UNSTABLE PERIODIC ORBITS	9	STABILITY	446
CRITICAL POINT	1	STABILITY	447
BISTABILITY	4	STABILITY	451
BIFURCATION DIAGRAM	6	STABILITY	457
BISTABLE	3	STABILITY	460
LARGEST LYAPUNOV EXPONENT	8	STABILITY	468
BIFURCATION DIAGRAMS	8	STABILITY	476
BIFURCATION POINT	5	STABILITY	481
STABILIZING	4	STABILITY	485
BIFURCATION ANALYSIS	2	STABILITY	487
UNSTABLE PERIODIC	0	STABILITY	487
LINEAR STABILITY	0	STABILITY	487
STABILIZATION	3	STABILITY	490
STABILITY ANALYSIS	0	STABILITY	490
HOPF BIFURCATION	1	STABILITY	491
LYAPUNOV EXPONENTS	6	STABILITY	497

INSTABILITIES	6	STABILITY	503
LYAPUNOV EXPONENT	5	STABILITY	508
INSTABILITY	4	STABILITY	512
UNSTABLE	4	STABILITY	516
LYAPUNOV	1	STABILITY	517
STABLE	2	STABILITY	519
STABILITY	4	STABILITY	523
EQUILIBRIUM STATE	4	STATES	4
EIGENFUNCTION	8	STATES	12
TRANSITION STATE	5	STATES	17
STATIONARY STATE	7	STATES	24
COHERENT STRUCTURES	6	STATES	30
EIGENVECTOR	8	STATES	38
STATIONARY STATES	7	STATES	45
STATE-SPACE	4	STATES	49
EIGENVECTORS	6	STATES	55
BOUND STATES	5	STATES	60
EIGENMODES	5	STATES	65
COHERENT STATES	9	STATES	74
EIGENSTATES	5	STATES	79
EIGENFUNCTIONS	6	STATES	85
EIGENVALUE	1	STATES	86
EIGENVALUES	5	STATES	91
STATES	7	STATES	98
STATISTICAL MECHANICS	10	STATISTICS	10
STATISTICAL ANALYSIS	11	STATISTICS	21
BAYESIAN	6	STATISTICS	27
MARKOV CHAIN	7	STATISTICS	34
BOSE-EINSTEIN CONDENSATE	9	STATISTICS	43
SPECTRAL STATISTICS	12	STATISTICS	55
ERGODICITY	5	STATISTICS	60
BOSE-EINSTEIN	4	STATISTICS	64
STATISTICAL PROPERTIES	5	STATISTICS	69
STATISTICS	7	STATISTICS	76
STATISTICAL	5	STATISTICS	81
SYNCHRONIZATION OF CHAOTIC	11	SYNCHRONICITY	11
PHASE-MATCHING	4	SYNCHRONICITY	15
GLOBAL SYNCHRONIZATION	7	SYNCHRONICITY	22
PHASE-LOCKING	7	SYNCHRONICITY	29
DISCRETE BREATHERS	8	SYNCHRONICITY	37
SYNCHRONIZATION ERROR	6	SYNCHRONICITY	43

MODE-LOCKED	7	SYNCHRONICITY	50
SYNCHRONIZATION OF TWO	8	SYNCHRONICITY	58
SYNCHRONIZED CHAOTIC	5	SYNCHRONICITY	63
DESYNCHRONIZATION	6	SYNCHRONICITY	69
GENERALIZED SYNCHRONIZATION	5	SYNCHRONICITY	74
SYNCHRONISATION	4	SYNCHRONICITY	78
SYNCHRONIZING	6	SYNCHRONICITY	84
CHAOTIC SYNCHRONIZATION	3	SYNCHRONICITY	87
PHASE-LOCKED	6	SYNCHRONICITY	93
PHASE LOCKING	3	SYNCHRONICITY	96
SYNCHRONY	1	SYNCHRONICITY	97
CHAOS SYNCHRONIZATION	3	SYNCHRONICITY	100
SYNCHRONOUS	2	SYNCHRONICITY	102
PHASE SYNCHRONIZATION	2	SYNCHRONICITY	104
LOCKING	3	SYNCHRONICITY	107
SYNCHRONIZED	6	SYNCHRONICITY	113
SYNCHRONIZATION	1	SYNCHRONICITY	114
PLATE THEORY	6	THEORY	6
KOLMOGOROV-SINAI	9	THEORY	15
KURAMOTO-SIVASHINSKY	7	THEORY	22
HARTREE-FOCK	10	THEORY	32
FIELD THEORY	9	THEORY	41
FITZHUGH-NAGUMO	8	THEORY	49
KORTEWEG-DE VRIES	4	THEORY	53
MELNIKOV FUNCTION	10	THEORY	63
KDV EQUATION	3	THEORY	66
FLOQUET THEORY	11	THEORY	77
FOKKER-PLANCK EQUATION	5	THEORY	82
DYNAMICAL SYSTEMS THEORY	12	THEORY	94
THEORETICAL MODEL	11	THEORY	105
THEORETICAL ANALYSIS	7	THEORY	112
FOKKER-PLANCK	2	THEORY	114
GINZBURG-LANDAU EQUATION	2	THEORY	116
CHAOS THEORY	7	THEORY	123
RANDOM MATRIX THEORY	11	THEORY	134
THEORY	9	THEORY	143
NONADIABATIC	4	THERMODYNAMICS	4
SECOND LAW	7	THERMODYNAMICS	11

THERMODYNAMICS	2	THERMODYNAMICS	13
THERMODYNAMIC	6	THERMODYNAMICS	19
ADIABATIC	4	THERMODYNAMICS	23
INITIAL CONDITIONS	7	TIME BOUNDARY	7
INITIAL STATES	9	TIME BOUNDARY	16
STARTING POINT	7	TIME BOUNDARY	23
INITIAL CONDITION	7	TIME BOUNDARY	30
SENSITIVITY TO INITIAL	3	TIME BOUNDARY	33
DEPENDENCE ON INITIAL	8	TIME BOUNDARY	41
INITIAL VALUE	8	TIME BOUNDARY	49
INITIAL STATE	4	TIME BOUNDARY	53
INITIAL DATA	7	TIME BOUNDARY	60
WAVE EQUATIONS	11	WAVE	11
MUSIC	5	WAVE	16
LINEAR WAVES	4	WAVE	20
TRAVELLING WAVE	7	WAVE	27
SOLITARY WAVE SOLUTIONS	5	WAVE	32
WAVENUMBERS	6	WAVE	38
PERIODIC WAVES	3	WAVE	41
WATER WAVES	7	WAVE	48
NONLINEAR WAVES	7	WAVE	55
WAVE FRONTS	7	WAVE	62
ACOUSTIC WAVE	4	WAVE	66
SURFACE WAVES	5	WAVE	71
STANDING WAVE	6	WAVE	77
WAVE AMPLITUDE	8	WAVE	85
WAVE PACKETS	5	WAVE	90
SPIRAL WAVES	5	WAVE	95
ACOUSTIC WAVES	6	WAVE	101
STANDING WAVES	5	WAVE	106
WAVENUMBER	2	WAVE	108
GRAVITY WAVES	2	WAVE	110
SOLITARY WAVE	3	WAVE	113
TRAVELLING WAVES	0	WAVE	113
WAVE NUMBER	8	WAVE	121
NONLINEAR WAVE	2	WAVE	123
WAVEFORMS	3	WAVE	126
ROSSBY	1	WAVE	127
TRAVELING WAVES	5	WAVE	132
TRAVELING WAVE	4	WAVE	136
WAVEFORM	3	WAVE	139
SOLITARY WAVES	5	WAVE	144
WAVE PACKET	5	WAVE	149

WAVES	2	WAVE	151

APPENDIX 6B – ABSTRACT MANUAL TAXONOMY – NON-MARGINAL UTILITY

TABLE A6B-1 – ABSTRACT TAXONOMY

PHRASE	#ABS NMU	SUB-CATEGORY	SUB ABS NMU	SUB PH NMU
BIOLOGICAL	90	BIOLOGY	90	123
BIOLOGY	28	BIOLOGY	118	151
CIRCADIAN	9	BIOLOGY	127	171
DNA	14	BIOLOGY	141	193
ENZYME	6	BIOLOGY	147	207
GENETIC	32	BIOLOGY	179	258
MUSCLE	12	BIOLOGY	191	276
NERVE	5	BIOLOGY	196	287
ORGANISMS	18	BIOLOGY	214	312
PLANKTON	7	BIOLOGY	221	330
PROTEIN	14	BIOLOGY	235	361
PROTEINS	11	BIOLOGY	246	374
BRAIN	47	BRAIN	47	87
CEREBRAL	13	BRAIN	60	101
CORTEX	20	BRAIN	80	131
CORTICAL	25	BRAIN	105	167
EEG	37	BRAIN	142	270
EPILEPSY	11	BRAIN	153	284
EPILEPTIC	10	BRAIN	163	300
HIPPOCAMPAL	9	BRAIN	172	315
HIPPOCAMPUS	10	BRAIN	182	331
NEURAL	185	BRAIN	367	625
NEURON	38	BRAIN	405	685
NEURONAL	31	BRAIN	436	727
NEURONS	70	BRAIN	506	877
REM	8	BRAIN	514	898
SCHIZOPHRENIA	9	BRAIN	523	920
SCHIZOPHRENIC	5	BRAIN	528	933
SEIZURE	13	BRAIN	541	962
SEIZURES	8	BRAIN	549	983
SLEEP	18	BRAIN	567	1074
SYNAPSES	12	BRAIN	579	1092
SYNAPTIC	27	BRAIN	606	1136
ANOMALOUS DIFFUSION	10	CHEMISTRY	10	11

AUTOCATALYTIC	15	CHEMISTRY	25	27
BELOUSOV-ZHABOTINSKY	18	CHEMISTRY	43	45
CAPACITORS	9	CHEMISTRY	52	58
CATALYTIC	26	CHEMISTRY	78	93
CHEMICAL REACTION	12	CHEMISTRY	90	107
CHEMISTRY	12	CHEMISTRY	102	120
CO OXIDATION	10	CHEMISTRY	112	131
DIFFUSION COEFFICIENT	23	CHEMISTRY	135	161
DIFFUSION EQUATION	14	CHEMISTRY	149	178
ELECTROCHEMICAL	14	CHEMISTRY	163	196
ELECTRODE	17	CHEMISTRY	180	222
HEAT TRANSFER COEFFICIENT	4	CHEMISTRY	184	237
RATE EQUATIONS	13	CHEMISTRY	197	251
REACTANTS	7	CHEMISTRY	204	263
REACTION RATE	9	CHEMISTRY	213	275
REACTION-DIFFUSION	46	CHEMISTRY	259	327
REACTIONS	41	CHEMISTRY	300	385
SOLUTE	9	CHEMISTRY	309	396
ASTEROID	7	COSMOLOGY	7	19
BLACK HOLE	18	COSMOLOGY	25	52
BLACK HOLES	15	COSMOLOGY	40	72
COMET	4	COSMOLOGY	44	83
CORONAL	8	COSMOLOGY	52	95
COSMOLOGICAL	33	COSMOLOGY	85	134
COSMOLOGY	14	COSMOLOGY	99	157
CRATERS	3	COSMOLOGY	102	173
DARK MATTER	5	COSMOLOGY	107	184
DUSTY PLASMA	11	COSMOLOGY	118	196
GALACTIC	20	COSMOLOGY	138	221
GALAXIES	18	COSMOLOGY	156	269
GALAXY	19	COSMOLOGY	175	311
INFLATIONARY	15	COSMOLOGY	190	332
INFLATON	11	COSMOLOGY	201	353
INTERSTELLAR	9	COSMOLOGY	210	364
JUPITER	10	COSMOLOGY	220	383
MARS	6	COSMOLOGY	226	398
PLANETARY	26	COSMOLOGY	252	444
PLANETS	11	COSMOLOGY	263	463
RELATIVITY	10	COSMOLOGY	273	474
SATELLITES	13	COSMOLOGY	286	497
SOLAR SYSTEM	10	COSMOLOGY	296	515
SOLAR WIND	7	COSMOLOGY	303	527
STELLAR	19	COSMOLOGY	322	553

SUNSPOT	13	COSMOLOGY	335	572
SUPERGRAVITY	18	COSMOLOGY	353	594
ATMOSPHERE	35	ENVIRONMENT	35	46
ATMOSPHERIC	54	ENVIRONMENT	89	123
BAROTROPIC	16	ENVIRONMENT	105	147
CLIMATE	32	ENVIRONMENT	137	229
CYCLONE	6	ENVIRONMENT	143	251
ECOLOGICAL	26	ENVIRONMENT	169	284
ECOLOGY	15	ENVIRONMENT	184	302
EL NINO	17	ENVIRONMENT	201	338
ENVIRONMENTAL	34	ENVIRONMENT	235	380
HURRICANE	3	ENVIRONMENT	238	391
INTERANNUAL VARIABILITY	7	ENVIRONMENT	245	402
LA NINA	7	ENVIRONMENT	252	417
MONSOON	5	ENVIRONMENT	257	433
NORTH ATLANTIC	13	ENVIRONMENT	270	452
RAINFALL	12	ENVIRONMENT	282	507
SOUTHERN OSCILLATION	10	ENVIRONMENT	292	518
STORM	7	ENVIRONMENT	299	529
STORMS	2	ENVIRONMENT	301	540
STRATOSPHERIC	7	ENVIRONMENT	308	551
TROPICAL CYCLONE	3	ENVIRONMENT	311	569
WEATHER	19	ENVIRONMENT	330	595
WIND	74	ENVIRONMENT	404	738
ADVECTION	40	FLUID FLOW	40	52
ADVECTION-DIFFUSION	10	FLUID FLOW	50	64
ANGLE OF ATTACK	5	FLUID FLOW	55	76
BOUNDARY LAYER	32	FLUID FLOW	87	122
CAVITATION	8	FLUID FLOW	95	142
CHAOTIC FLOWS	15	FLUID FLOW	110	159
CONVECTION	108	FLUID FLOW	218	370
CORIOLIS FORCE	7	FLUID FLOW	225	381
COUETTE	13	FLUID FLOW	238	399
CRITICAL REYNOLDS	6	FLUID FLOW	244	411
EKMAN LAYER	4	FLUID FLOW	248	422
FLOW FIELD	19	FLUID FLOW	267	446
FLOW FIELDS	12	FLUID FLOW	279	459
FLOW PATTERNS	13	FLUID FLOW	292	482
FLOW RATE	16	FLUID FLOW	308	508
FLOW VISUALIZATION	9	FLUID FLOW	317	519
FLUID DYNAMICS	19	FLUID FLOW	336	542
FLUID FLOW	15	FLUID FLOW	351	559
FLUID MOTION	13	FLUID FLOW	364	575
FLUIDIZATION	3	FLUID FLOW	367	588

GRASHOF	8	FLUID FLOW	375	600
HEAT CONDUCTION	11	FLUID FLOW	386	611
HYDRODYNAMICS	17	FLUID FLOW	403	628
INVISCID	24	FLUID FLOW	427	655
LAMINAR	34	FLUID FLOW	461	695
MAGNETOHYDRODYNAMIC	20	FLUID FLOW	481	719
MASS FLOW	5	FLUID FLOW	486	730
MEAN FLOW	10	FLUID FLOW	496	746
MHD	21	FLUID FLOW	517	780
NAVIER-STOKES EQUATIONS	30	FLUID FLOW	547	813
NON-NEWTONIAN	11	FLUID FLOW	558	829
NUSSELT	11	FLUID FLOW	569	842
PRANDTL NUMBER	25	FLUID FLOW	594	872
RAYLEIGH NUMBER	27	FLUID FLOW	621	910
RAYLEIGH NUMBERS	9	FLUID FLOW	630	927
RAYLEIGH-BENARD	12	FLUID FLOW	642	939
REYNOLDS NUMBER	42	FLUID FLOW	684	998
REYNOLDS NUMBERS	27	FLUID FLOW	711	1044
REYNOLDS STRESS	5	FLUID FLOW	716	1057
SECONDARY FLOW	8	FLUID FLOW	724	1073
SHEAR FLOW	19	FLUID FLOW	743	1101
SHEAR LAYER	9	FLUID FLOW	752	1114
SHOCK WAVE	13	FLUID FLOW	765	1130
SUPERSONIC	14	FLUID FLOW	779	1144
TRANSONIC	10	FLUID FLOW	789	1158
TRANSPORT PROPERTIES	11	FLUID FLOW	800	1169
TURBULENCE	105	FLUID FLOW	905	1344
VORTEX MOTION	11	FLUID FLOW	916	1357
VORTICES	65	FLUID FLOW	981	1478
VORTICITY	44	FLUID FLOW	1025	1581
BEDROCK	7	GEOLOGY	7	12
EARTHQUAKE	40	GEOLOGY	47	83
EARTHQUAKES	21	GEOLOGY	68	112
GEOPHYSICAL	15	GEOLOGY	83	132
GROUND MOTION	11	GEOLOGY	94	153
GROUND MOTIONS	12	GEOLOGY	106	167
LANDSLIDE	4	GEOLOGY	110	182
SAND	7	GEOLOGY	117	193
SEDIMENT	19	GEOLOGY	136	228
SEDIMENTARY	7	GEOLOGY	143	239
SEDIMENTATION	9	GEOLOGY	152	250
SEDIMENTS	12	GEOLOGY	164	266
SEISMIC	41	GEOLOGY	205	356

SEISMIC ACTIVITY	5	GEOLOGY	210	368
SEISMICITY	6	GEOLOGY	216	379
SOIL	30	GEOLOGY	246	466
SOILS	9	GEOLOGY	255	495
TECTONIC	8	GEOLOGY	263	509
VOLCANIC	11	GEOLOGY	274	530
ENERGY PUMPING	4	LASER	4	13
LASER	247	LASER	251	472
LASERS	70	LASER	321	578
LASING	9	LASER	330	597
YAG	18	LASER	348	616
CRYSTALS	31	MATERIALS	31	45
DYNAMIC BUCKLING	6	MATERIALS	37	58
FERROMAGNETIC	14	MATERIALS	51	73
GLASSES	16	MATERIALS	67	96
MONOLAYER	8	MATERIALS	75	119
NONLINEAR ELASTIC	13	MATERIALS	88	132
PARTICLE DEPOSITION	4	MATERIALS	92	144
PLASTICITY	11	MATERIALS	103	158
POLYMER	25	MATERIALS	128	195
POLYMERS	15	MATERIALS	143	213
RHEOLOGICAL	7	MATERIALS	150	224
SPIN GLASSES	9	MATERIALS	159	235
STRAIN RATE	8	MATERIALS	167	246
SUPERCONDUCTORS	10	MATERIALS	177	257
VISCOELASTIC	40	MATERIALS	217	329
APNEA	4	MEDICAL	4	11
BLOOD PRESSURE	11	MEDICAL	15	38
CARDIOVASCULAR	19	MEDICAL	34	64
CERVICAL SPINE	3	MEDICAL	37	76
DISEASE	29	MEDICAL	66	138
FETUSES	3	MEDICAL	69	149
FIBRILLATION	11	MEDICAL	80	165
HEALTH	15	MEDICAL	95	185
HEALTHY SUBJECTS	9	MEDICAL	104	198
HEART RATE	26	MEDICAL	130	250
HEPATITIS	1	MEDICAL	131	262
HIV	2	MEDICAL	133	273
IMMUNITY	9	MEDICAL	142	284
INFECTION	11	MEDICAL	153	302
LUNG	9	MEDICAL	162	316
MEDICAL	7	MEDICAL	169	334
PACEMAKER	7	MEDICAL	176	349
RENAL	2	MEDICAL	178	362

RESPIRATORY MOVEMENT	2	MEDICAL	180	373
RETINAL	3	MEDICAL	183	386
VENTRICULAR	13	MEDICAL	196	412
VIRUS	8	MEDICAL	204	432
MARINE	14	OCEAN	14	22
MOORING LINES	5	OCEAN	19	33
OCEAN	46	OCEAN	65	118
OCEANIC	18	OCEAN	83	138
SEA	59	OCEAN	142	226
SHALLOW WATER	10	OCEAN	152	237
SHIPS	7	OCEAN	159	249
WAVE DRIFT	8	OCEAN	167	261
BEAM	113	OPTICAL	113	205
BEAMS	42	OPTICAL	155	260
DIFFRACTION	22	OPTICAL	177	296
OPTICAL	295	OPTICAL	472	757
OPTICS	27	OPTICAL	499	790
OPTOELECTRONIC	7	OPTICAL	506	802
PLASMA	127	PLASMA	127	267
PLASMAS	34	PLASMA	161	306
TOKAMAK	13	PLASMA	174	326
POPULATION GROWTH	9	POPULATION	9	17
PREDATOR-PREY	12	POPULATION	21	40
PREDATORS	12	POPULATION	33	68
DIELECTRIC	25	SOLID STATE	25	40
DIODE	25	SOLID STATE	50	74
DIODES	17	SOLID STATE	67	96
GAAS	14	SOLID STATE	81	114
MICROCHIP	9	SOLID STATE	90	125
SEMICONDUCTOR	88	SOLID STATE	178	229
SILICON	20	SOLID STATE	198	252
SOLID-STATE	12	SOLID STATE	210	268
TUNNELING	43	SOLID STATE	253	325
TUNNELLING	11	SOLID STATE	264	348
BOUNDARY CONDITION	19	SPATIAL BOUNDARY	19	19
BOUNDARY CONDITIONS	119	SPATIAL BOUNDARY	138	166
BOUNDARY VALUE	31	SPATIAL BOUNDARY	169	206
DIRICHLET	28	SPATIAL BOUNDARY	197	237
DOMAIN WALL	15	SPATIAL BOUNDARY	212	262

DOMAIN WALLS	19	SPATIAL BOUNDARY	231	284
FREE BOUNDARY	12	SPATIAL BOUNDARY	243	303
FREE SURFACE	16	SPATIAL BOUNDARY	259	322
NEUMANN	24	SPATIAL BOUNDARY	283	349
PERIODIC BOUNDARY	31	SPATIAL BOUNDARY	314	384
DEPENDENCE ON INITIAL	16	TIME BOUNDARY	16	17
INITIAL CONDITION	14	TIME BOUNDARY	30	32
INITIAL CONDITIONS	159	TIME BOUNDARY	189	225
INITIAL DATA	27	TIME BOUNDARY	216	260
INITIAL STATE	28	TIME BOUNDARY	244	290
INITIAL STATES	11	TIME BOUNDARY	255	301
INITIAL VALUE	18	TIME BOUNDARY	273	324
SENSITIVITY TO INITIAL	14	TIME BOUNDARY	287	341
STARTING POINT	13	TIME BOUNDARY	300	354
COMBUSTION	9	COMBUSTION	9	20
DETONATION	6	COMBUSTION	15	41
FIRE	16	COMBUSTION	31	70
FLAME	13	COMBUSTION	44	98
PROPULSION	6	COMBUSTION	50	109
CIRCUIT	102	CIRCUITS	102	168
CIRCUITS	45	CIRCUITS	147	242
JOSEPHSON JUNCTION	14	CIRCUITS	161	260
JOSEPHSON JUNCTIONS	13	CIRCUITS	174	280
ON-OFF INTERMITTENCY	26	CIRCUITS	200	315
SWITCHES	20	CIRCUITS	220	338
CODING	19	CODE	19	22
DECODING	10	CODE	29	41
ENCRYPTION	15	CODE	44	70
SECURITY	17	CODE	61	97
RADAR	11	COMMUNICATION	11	23
ANHARMONIC	32	SIGNALS	32	40
COMMUNICATION	90	SIGNALS	122	173
COMMUNICATIONS	35	SIGNALS	157	227
HARMONIC	198	SIGNALS	355	470
HARMONICS	44	SIGNALS	399	535
INFORMATION PROCESSING	16	SIGNALS	415	554
KALMAN FILTER	15	SIGNALS	430	572
MUTUAL INFORMATION	15	SIGNALS	445	591

RADIO	17	SIGNALS	462	619
SIGNAL	279	SIGNALS	741	1072
SIGNALS	201	SIGNALS	942	1370
SPREAD SPECTRUM	7	SIGNALS	949	1381
SUBHARMONIC	31	SIGNALS	980	1424
SUBHARMONICS	9	SIGNALS	989	1435
TIME SERIES	217	SIGNALS	1206	1761
TIME-SERIES	25	SIGNALS	1231	1795
VOLTERRA SERIES	7	SIGNALS	1238	1806
BACKPROPAGATION	8	CONTROL	8	12
CONTROL	581	CONTROL	589	1318
CONTROLLABILITY	14	CONTROL	603	1339
CONTROLLED	137	CONTROL	740	1494
CONTROLLER	117	CONTROL	857	1725
CONTROLLERS	34	CONTROL	891	1771
CONTROLLING	91	CONTROL	982	1873
CONTROLS	48	CONTROL	1030	1939
FEEDBACK	310	CONTROL	1340	2462
FEEDBACKS	6	CONTROL	1346	2473
FEEDFORWARD	15	CONTROL	1361	2494
COUPLED CHAOTIC	45	COUPLING	45	51
COUPLED EQUATIONS	11	COUPLING	56	63
COUPLED NONLINEAR	39	COUPLING	95	106
COUPLED SYSTEM	27	COUPLING	122	140
COUPLED SYSTEMS	13	COUPLING	135	154
COUPLING COEFFICIENTS	6	COUPLING	141	165
COUPLING CONSTANT	13	COUPLING	154	183
COUPLING STRENGTH	44	COUPLING	198	230
DIFFUSIVELY COUPLED	10	COUPLING	208	241
GLOBALLY COUPLED	21	COUPLING	229	268
NONLINEAR COUPLING	15	COUPLING	244	285
STRONG COUPLING	17	COUPLING	261	303
STRONGLY COUPLED	16	COUPLING	277	319
UNIDIRECTIONALLY COUPLED	13	COUPLING	290	335
WEAK COUPLING	12	COUPLING	302	347
WEAKLY COUPLED	17	COUPLING	319	367
RESONANCE	283	RESONANCE	283	439
RESONANT	149	RESONANCE	432	640
RESONATOR	24	RESONANCE	456	677
RESONATORS	9	RESONANCE	465	691
DESYNCHRONIZATION	16	SYNCHRONICITY	16	18
DISCRETE BREATHERS	8	SYNCHRONICITY	24	30
LOCKING	56	SYNCHRONICITY	80	113

MODE-LOCKED	8	SYNCHRONICITY	88	127
PHASE-LOCKED	22	SYNCHRONICITY	110	153
PHASE-MATCHING	6	SYNCHRONICITY	116	164
SYNCHRONISATION	8	SYNCHRONICITY	124	185
SYNCHRONIZATION	283	SYNCHRONICITY	407	779
SYNCHRONIZED	108	SYNCHRONICITY	515	922
SYNCHRONIZING	16	SYNCHRONICITY	531	946
SYNCHRONOUS	45	SYNCHRONICITY	576	1003
SYNCHRONY	15	SYNCHRONICITY	591	1036
CLOSED ORBITS	12	OSCILLATIONS	12	16
CONDUCTANCE FLUCTUATIONS	8	OSCILLATIONS	20	27
CYCLES	133	OSCILLATIONS	153	222
LIMIT CYCLE	67	OSCILLATIONS	220	309
OSCILLATE	33	OSCILLATIONS	253	342
OSCILLATES	29	OSCILLATIONS	282	371
OSCILLATING	105	OSCILLATIONS	387	492
OSCILLATION	291	OSCILLATIONS	678	889
OSCILLATIONS	516	OSCILLATIONS	1194	1717
OSCILLATOR	287	OSCILLATIONS	1481	2101
OSCILLATORS	200	OSCILLATIONS	1681	2392
OSCILLATORY	244	OSCILLATIONS	1925	2724
PRESSURE FLUCTUATIONS	5	OSCILLATIONS	1930	2736
VIBRATING	30	OSCILLATIONS	1960	2771
VIBRATION	83	OSCILLATIONS	2043	2910
VIBRATIONS	63	OSCILLATIONS	2106	3001
APERIODIC	35	PERIODICITY	35	47
CHAOTIC ORBIT	8	PERIODICITY	43	58
CIRCULAR ORBIT	11	PERIODICITY	54	69
CYCLIC	35	PERIODICITY	89	112
HOMOCLINIC ORBIT	11	PERIODICITY	100	125
HOMOCLINIC ORBITS	30	PERIODICITY	130	175
LIMIT-CYCLE	15	PERIODICITY	145	195
PERIOD DOUBLING	46	PERIODICITY	191	254
PERIOD- DOUBLING	11	PERIODICITY	202	265
PERIOD DOUBLINGS	9	PERIODICITY	211	277
PERIOD-DOUBLING	68	PERIODICITY	279	363
PERIODIC FORCING	19	PERIODICITY	298	387
PERIODIC MOTION	20	PERIODICITY	318	415
PERIODIC MOTIONS	11	PERIODICITY	329	431
PERIODIC ORBIT	82	PERIODICITY	411	522
PERIODIC ORBITS	219	PERIODICITY	630	833
PERIODIC POINTS	14	PERIODICITY	644	851
PERIODIC POTENTIAL	12	PERIODICITY	656	863

PERIODIC SOLUTION	29	PERIODICITY	685	897
PERIODIC STATES	8	PERIODICITY	693	908
PERIODICALLY FORCED	18	PERIODICITY	711	930
PERIODICITIES	10	PERIODICITY	721	941
PERIODICITY	41	PERIODICITY	762	990
QUASIPERIODIC	64	PERIODICITY	826	1074
QUASI-PERIODIC	64	PERIODICITY	890	1151
QUASI-PERIODIC ORBITS	9	PERIODICITY	899	1163
SPATIALLY PERIODIC	20	PERIODICITY	919	1186
ACOUSTIC WAVE	11	WAVE	11	14
ACOUSTIC WAVES	14	WAVE	25	34
GRAVITY WAVES	13	WAVE	38	56
LINEAR WAVES	4	WAVE	42	67
MUSIC	5	WAVE	47	78
NONLINEAR WAVE	24	WAVE	71	103
NONLINEAR WAVES	14	WAVE	85	117
PERIODIC WAVES	7	WAVE	92	130
ROSSBY	19	WAVE	111	156
SOLITARY WAVE	20	WAVE	131	179
SOLITARY WAVES	21	WAVE	152	211
SPIRAL WAVES	12	WAVE	164	230
STANDING WAVE	12	WAVE	176	245
STANDING WAVES	16	WAVE	192	267
SURFACE WAVES	12	WAVE	204	282
TRAVELING WAVE	16	WAVE	220	308
TRAVELING WAVES	23	WAVE	243	334
TRAVELLING WAVE	11	WAVE	254	346
TRAVELLING WAVES	16	WAVE	270	370
WATER WAVES	12	WAVE	282	383
WAVE AMPLITUDE	14	WAVE	296	398
WAVE EQUATIONS	11	WAVE	307	409
WAVE FRONTS	10	WAVE	317	423
WAVE NUMBER	20	WAVE	337	447
WAVE PACKET	23	WAVE	360	479
WAVE PACKETS	13	WAVE	373	495
WAVEFORM	24	WAVE	397	522
WAVEFORMS	17	WAVE	414	547
WAVENUMBER	15	WAVE	429	569
WAVENUMBERS	11	WAVE	440	581
CYCLOTRON	13	EXPERIMENTS	13	16
ELECTRIC FIELD	55	EXPERIMENTS	68	86
ELECTRIC FIELDS	18	EXPERIMENTS	86	108
ELECTROMAGNETIC FIELD	10	EXPERIMENTS	96	120
ELECTROMAGNETIC FIELDS	10	EXPERIMENTS	106	131

EXPERIMENTAL DATA	89	EXPERIMENTS	195	227
EXPERIMENTAL OBSERVATIONS	50	EXPERIMENTS	245	279
EXPERIMENTAL RESULTS	140	EXPERIMENTS	385	421
EXPERIMENTS	365	EXPERIMENTS	750	877
EXTERNAL FIELD	12	EXPERIMENTS	762	893
EXTERNAL MAGNETIC	14	EXPERIMENTS	776	908
MAGNETIC FIELD	149	EXPERIMENTS	925	1153
MAGNETIC FIELDS	35	EXPERIMENTS	960	1200
MEMS	6	EXPERIMENTS	966	1214
MICROSCOPE	9	EXPERIMENTS	975	1226
MICROSCOPY	19	EXPERIMENTS	994	1246
MOBILE ROBOT	6	EXPERIMENTS	1000	1257
SPECTROSCOPIC	13	EXPERIMENTS	1013	1271
SPECTROSCOPY	39	EXPERIMENTS	1052	1322
X-RAY	21	EXPERIMENTS	1073	1366
CYLINDER	42	GEOMETRY	42	77
CYLINDERS	27	GEOMETRY	69	113
CYLINDRICAL	75	GEOMETRY	144	201
FILM THICKNESS	9	GEOMETRY	153	216
GEOMETRIC	104	GEOMETRY	257	343
GEOMETRICAL	52	GEOMETRY	309	404
GEOMETRIES	35	GEOMETRY	344	444
GEOMETRY	124	GEOMETRY	468	597
SPHERES	15	GEOMETRY	483	617
SPHERICAL	74	GEOMETRY	557	705
THIN FILM	9	GEOMETRY	566	719
THIN FILMS	10	GEOMETRY	576	732
THIN PLATE	4	GEOMETRY	580	745
ALGEBRAIC EQUATIONS	13	MODEL AND SIM	13	13
CELLULAR AUTOMATA	10	MODEL AND SIM	23	26
CELLULAR AUTOMATON	10	MODEL AND SIM	33	37
CHAOTIC MODEL	10	MODEL AND SIM	43	50
COMPLEX GINZBURG-LANDAU EQUATION	22	MODEL AND SIM	65	72
COMPUTER SIMULATION	37	MODEL AND SIM	102	109
COMPUTER SIMULATIONS	46	MODEL AND SIM	148	156
DELAY DIFFERENTIAL EQUATIONS	10	MODEL AND SIM	158	167
DIFFERENCE EQUATION	15	MODEL AND SIM	173	185
DIFFERENCE EQUATIONS	23	MODEL AND SIM	196	211
DIFFERENTIAL EQUATIONS	238	MODEL AND SIM	434	485
DYNAMIC MODEL	25	MODEL AND SIM	459	512
DYNAMICAL EQUATIONS	19	MODEL AND SIM	478	533

ELLIPTIC FUNCTION	9	MODEL AND SIM	487	544
ELLIPTIC FUNCTIONS	11	MODEL AND SIM	498	556
EQUATION OF MOTION	39	MODEL AND SIM	537	599
EQUATIONS OF MOTION	144	MODEL AND SIM	681	764
FINITE ELEMENT METHOD	24	MODEL AND SIM	705	789
GALERKIN METHOD	11	MODEL AND SIM	716	800
GENERAL MODEL	12	MODEL AND SIM	728	813
GENETIC ALGORITHM	10	MODEL AND SIM	738	828
LINEAR MODEL	15	MODEL AND SIM	753	845
MATHEMATICAL MODEL	62	MODEL AND SIM	815	908
MODEL BASED	31	MODEL AND SIM	846	940
MODEL EQUATIONS	14	MODEL AND SIM	860	955
MODELED	124	MODEL AND SIM	984	1090
MODELING	138	MODEL AND SIM	1122	1261
MODELLED	33	MODEL AND SIM	1155	1298
MODELLING	41	MODEL AND SIM	1196	1347
MONTE CARLO SIMULATION	11	MODEL AND SIM	1207	1358
NETWORK MODEL	25	MODEL AND SIM	1232	1386
NONLINEAR DIFFERENTIAL EQUATION	13	MODEL AND SIM	1245	1399
NONLINEAR EQUATIONS	37	MODEL AND SIM	1282	1437
NONLINEAR MODEL	32	MODEL AND SIM	1314	1479
NONLINEAR MODELS	19	MODEL AND SIM	1333	1500
NONLINEAR ORDINARY DIFFERENTIAL	13	MODEL AND SIM	1346	1513
NONLINEAR PARTIAL DIFFERENTIAL	16	MODEL AND SIM	1362	1530
NONLINEAR SCHRODINGER EQUATION	36	MODEL AND SIM	1398	1572
NONLINEAR SCHRODINGER EQUATIONS	13	MODEL AND SIM	1411	1587
NUMERICAL MODEL	16	MODEL AND SIM	1427	1606
NUMERICAL SIMULATION	83	MODEL AND SIM	1510	1691
NUMERICAL SIMULATIONS	222	MODEL AND SIM	1732	1924
ODE	16	MODEL AND SIM	1748	1949
ODES	19	MODEL AND SIM	1767	1974
ORDINARY DIFFERENTIAL EQUATION	18	MODEL AND SIM	1785	1992
PARTIAL DIFFERENTIAL EQUATION	24	MODEL AND SIM	1809	2018
RANDOM WALKS	10	MODEL AND SIM	1819	2030
RENORMALIZATION GROUP	12	MODEL AND SIM	1831	2042
RUNGE-KUTTA	20	MODEL AND SIM	1851	2062
SIMULATE	63	MODEL AND SIM	1914	2126

STOCHASTIC DIFFERENTIAL EQUATION	10	MODEL AND SIM	1924	2139
WAVELET TRANSFORM	7	MODEL AND SIM	1931	2151
ATTRACTION	72	ATTRACTORS	72	84
ATTRACTOR	369	ATTRACTORS	441	642
ATTRACTORS	277	ATTRACTORS	718	1039
BASIN	81	ATTRACTORS	799	1189
CHAOTIC MOTIONS	28	CHAOS	28	34
CHAOTIC ORBITS	19	CHAOS	47	68
CHAOTIC REGIME	33	CHAOS	80	104
CHAOTIC REGIMES	15	CHAOS	95	120
CHAOTIC SCATTERING	15	CHAOS	110	139
CHAOTIC STATE	20	CHAOS	130	162
CHAOTIC STATES	20	CHAOS	150	184
CHAOTIC SYSTEMS	150	CHAOS	300	388
CHAOTIC TRAJECTORIES	11	CHAOS	311	399
CHAOTICITY	20	CHAOS	331	420
CLASSICALLY CHAOTIC	20	CHAOS	351	440
DETERMINISTIC CHAOS	31	CHAOS	382	473
DETERMINISTIC CHAOTIC	15	CHAOS	397	488
HYPERCHAOTIC	20	CHAOS	417	523
LAGRANGIAN CHAOS	6	CHAOS	423	535
NONLINEAR CHAOTIC	10	CHAOS	433	548
ONSET OF CHAOS	21	CHAOS	454	571
ROBUST CHAOS	5	CHAOS	459	588
ROUTE TO CHAOS	25	CHAOS	484	616
ROUTES TO CHAOS	14	CHAOS	498	631
SPATIOTEMPORAL CHAOS	32	CHAOS	530	669
TRANSIENT CHAOS	10	CHAOS	540	680
TRANSITION TO CHAOS	14	CHAOS	554	694
ASYMPTOTIC ANALYSIS	15	EVOLUTION	15	16
ASYMPTOTIC EXPANSION	10	EVOLUTION	25	27
ASYMPTOTIC EXPANSIONS	11	EVOLUTION	36	39
CHAOTIC DYNAMICS	126	EVOLUTION	162	190
DECAY RATE	18	EVOLUTION	180	212
DYNAMIC SYSTEM	28	EVOLUTION	208	245
DYNAMICAL MODEL	22	EVOLUTION	230	268
DYNAMICAL SYSTEM	213	EVOLUTION	443	513
DYNAMICAL SYSTEMS	304	EVOLUTION	747	881
EVOLUTION EQUATION	16	EVOLUTION	763	901
EVOLUTION EQUATIONS	29	EVOLUTION	792	934
EVOLUTION OPERATOR	17	EVOLUTION	809	954
EVOLUTIONARY	34	EVOLUTION	843	1001
EXPONENTIAL DECAY	13	EVOLUTION	856	1014

GROWTH RATE	27	EVOLUTION	883	1048
GROWTH RATES	18	EVOLUTION	901	1075
NON-LINEAR DYNAMICAL	16	EVOLUTION	917	1096
NONLINEAR DYNAMICS	108	EVOLUTION	1025	1216
NON-LINEAR DYNAMICS	14	EVOLUTION	1039	1232
NONLINEAR EVOLUTION	30	EVOLUTION	1069	1264
POPULATION DYNAMICS	34	EVOLUTION	1103	1312
RELAXATION TIME	11	EVOLUTION	1114	1326
STOCHASTIC DYNAMICAL	10	EVOLUTION	1124	1338
SYSTEM DYNAMICS	24	EVOLUTION	1148	1367
TEMPORAL EVOLUTION	14	EVOLUTION	1162	1381
TIME EVOLUTION	56	EVOLUTION	1218	1443
CODIMENSION	19	DIMENSIONALITY	19	21
CODIMENSION-2	8	DIMENSIONALITY	27	34
CORRELATION DIMENSION	83	DIMENSIONALITY	110	158
CORRELATION DIMENSIONS	12	DIMENSIONALITY	122	174
DEGREE OF FREEDOM	25	DIMENSIONALITY	147	202
DEGREES OF FREEDOM	99	DIMENSIONALITY	246	328
DIMENSIONALITY	31	DIMENSIONALITY	277	365
EMBEDDING DIMENSION	13	DIMENSIONALITY	290	381
FINITE DIMENSIONAL	8	DIMENSIONALITY	298	392
FINITE-DIMENSIONAL	19	DIMENSIONALITY	317	412
FOUR-DIMENSIONAL	26	DIMENSIONALITY	343	438
GENERALIZED DIMENSIONS	6	DIMENSIONALITY	349	452
HAUSDORFF DIMENSION	12	DIMENSIONALITY	361	467
HIGH-DIMENSIONAL	19	DIMENSIONALITY	380	493
HIGHER DIMENSIONAL	12	DIMENSIONALITY	392	505
HIGHER-DIMENSIONAL	9	DIMENSIONALITY	401	516
INFINITE-DIMENSIONAL	16	DIMENSIONALITY	417	533
LOW DIMENSIONAL	11	DIMENSIONALITY	428	544
LOW-DIMENSIONAL	43	DIMENSIONALITY	471	595
MULTIDIMENSIONAL	20	DIMENSIONALITY	491	616
DYNAMICAL LOCALIZATION	9	LOCALIZATION	9	11
LOCAL DYNAMICS	17	LOCALIZATION	26	29
LOCALIZATION	85	LOCALIZATION	111	161
SPATIALLY LOCALIZED	11	LOCALIZATION	122	173
ATOMS	76	QUANTUM	76	109
BILLIARD	54	QUANTUM	130	192
BILLIARDS	41	QUANTUM	171	253
CHAOTIC QUANTUM	14	QUANTUM	185	267
CHARGED PARTICLE	9	QUANTUM	194	278
COUPLED MAP LATTICE	17	QUANTUM	211	297
COUPLED MAP LATTICES	14	QUANTUM	225	313
COUPLED NONLINEAR	13	QUANTUM	238	327

SCHRODINGER				
ELECTRON	136	QUANTUM	374	571
ELECTRONS	62	QUANTUM	436	663
EXCITATION ENERGY	11	QUANTUM	447	677
GROUND STATE	30	QUANTUM	477	720
INTRAMOLECULAR	9	QUANTUM	486	731
ION	60	QUANTUM	546	833
IONS	36	QUANTUM	582	890
MOLECULAR DYNAMICS	20	QUANTUM	602	912
MOLECULE	20	QUANTUM	622	939
MOLECULES	58	QUANTUM	680	1004
NUCLEI	31	QUANTUM	711	1045
NUCLEUS	21	QUANTUM	732	1082
PROBABILITY DENSITY	40	QUANTUM	772	1126
PROTON	9	QUANTUM	781	1141
QUANTUM CHAOS	66	QUANTUM	847	1220
QUANTUM CHAOTIC	14	QUANTUM	861	1235
QUANTUM COMPUTER	7	QUANTUM	868	1250
QUANTUM DOT	21	QUANTUM	889	1280
QUANTUM DOTS	22	QUANTUM	911	1308
QUANTUM DYNAMICS	16	QUANTUM	927	1325
QUANTUM INTERFERENCE	13	QUANTUM	940	1339
QUANTUM MECHANICAL	24	QUANTUM	964	1369
QUANTUM MECHANICS	21	QUANTUM	985	1393
QUANTUM STATES	20	QUANTUM	1005	1418
QUANTUM SYSTEM	22	QUANTUM	1027	1441
QUANTUM SYSTEMS	28	QUANTUM	1055	1470
QUANTUM-MECHANICAL	11	QUANTUM	1066	1482
SCHRODINGER EQUATION	59	QUANTUM	1125	1550
SCHRODINGER EQUATIONS	14	QUANTUM	1139	1566
SUPERLATTICE	13	QUANTUM	1152	1587
SUPERLATTICES	15	QUANTUM	1167	1612
WAVE EQUATION	20	QUANTUM	1187	1634
WAVE FUNCTION	23	QUANTUM	1210	1670
FRACTAL	150	SCALING	150	273
FRACTALS	18	SCALING	168	299
LARGE-SCALE	62	SCALING	230	377
LENGTH SCALE	17	SCALING	247	399
LENGTH SCALES	14	SCALING	261	416
MULTIFRACTAL	26	SCALING	287	458
MULTIPLE SCALES	40	SCALING	327	499
SCALED	23	SCALING	350	526
SCALING	168	SCALING	518	741
SELF-SIMILAR	29	SCALING	547	783

SELF-SIMILARITY	10	SCALING	557	794
SMALL-SCALE	24	SCALING	581	831
TIME SCALE	47	SCALING	628	890
TIME SCALES	58	SCALING	686	962
TIMESCALE	27	SCALING	713	993
TIME-SCALE	9	SCALING	722	1005
TIMESCALES	17	SCALING	739	1023
CHAOTIC MAP	10	MAPS	10	11
CHAOTIC MAPS	24	MAPS	34	43
COUPLED MAP	36	MAPS	70	87
HENON MAP	14	MAPS	84	103
INVARIANT MANIFOLD	19	MAPS	103	128
INVARIANT MANIFOLDS	15	MAPS	118	148
LOGISTIC MAP	27	MAPS	145	176
LOGISTIC MAPS	14	MAPS	159	190
MANIFOLD	109	MAPS	268	345
MANIFOLDS	67	MAPS	335	433
MAP LATTICES	15	MAPS	350	452
MAPPING	89	MAPS	439	558
MAPPINGS	29	MAPS	468	594
NORMAL FORM	47	MAPS	515	672
ONE-DIMENSIONAL MAP	9	MAPS	524	684
POINCARE MAP	40	MAPS	564	734
POINCARE MAPS	20	MAPS	584	755
POINCARE SECTION	10	MAPS	594	767
POINCARE SECTIONS	23	MAPS	617	793
RETURN MAP	23	MAPS	640	818
STANDARD MAP	15	MAPS	655	836
ASYMPTOTIC STABILITY	28	STABILITY	28	30
ASYMPTOTICALLY STABLE	16	STABILITY	44	50
BIFURCATE	18	STABILITY	62	69
BIFURCATING	19	STABILITY	81	96
BIFURCATION	731	STABILITY	812	1345
BIFURCATIONS	310	STABILITY	1122	1817
BISTABILITY	34	STABILITY	1156	1862
BISTABLE	35	STABILITY	1191	1909
CRITICAL POINT	29	STABILITY	1220	1952
CRITICAL POINTS	20	STABILITY	1240	1980
DESTABILIZATION	11	STABILITY	1251	1993
DESTABILIZING	23	STABILITY	1274	2017
DYNAMIC STABILITY	10	STABILITY	1284	2028
EQUILIBRIUM POINT	19	STABILITY	1303	2050
EQUILIBRIUM POINTS	15	STABILITY	1318	2068
EXPONENTIALLY STABLE	10	STABILITY	1328	2080

GLOBAL STABILITY	11	STABILITY	1339	2093
INSTABILITIES	135	STABILITY	1474	2273
INSTABILITY	299	STABILITY	1773	2734
LIAPUNOV	8	STABILITY	1781	2745
LINEAR STABILITY	70	STABILITY	1851	2821
LOCAL STABILITY	14	STABILITY	1865	2841
LOSS OF STABILITY	14	STABILITY	1879	2856
LYAPUNOV	361	STABILITY	2240	3361
MAXIMUM LYAPUNOV	12	STABILITY	2252	3374
METASTABLE	19	STABILITY	2271	3399
MULTISTABILITY	16	STABILITY	2287	3418
NONLINEAR STABILITY	26	STABILITY	2313	3448
STABILITY ANALYSIS	95	STABILITY	2408	3558
STABILITY BOUNDARIES	13	STABILITY	2421	3573
STABILITY CONDITIONS	13	STABILITY	2434	3586
STABILITY CRITERION	11	STABILITY	2445	3597
STABILITY PROPERTIES	25	STABILITY	2470	3624
STABILITY REGION	6	STABILITY	2476	3635
STABILITY THEORY	11	STABILITY	2487	3646
STABILIZATION	67	STABILITY	2554	3730
STABILIZE	35	STABILITY	2589	3767
STABILIZED	30	STABILITY	2619	3800
STABILIZES	13	STABILITY	2632	3814
STABILIZING	50	STABILITY	2682	3874
STABLE AND UNSTABLE	31	STABILITY	2713	3907
STABLE EQUILIBRIUM	9	STABILITY	2722	3918
STABLE LIMIT	11	STABILITY	2733	3930
STABLE PERIODIC	25	STABILITY	2758	3956
STABLE STATES	11	STABILITY	2769	3968
TRANSIENT STABILITY	5	STABILITY	2774	3979
UNSTABLE	346	STABILITY	3120	4443
UNSTABLE MODES	13	STABILITY	3133	4461
UNSTABLE PERIODIC	60	STABILITY	3193	4529
VOLTAGE STABILITY	6	STABILITY	3199	4540
NONLINEAR EFFECTS	37	NONLINEAR	37	39
NONLINEAR EQUATION	25	NONLINEAR	62	64
NONLINEAR FUNCTION	14	NONLINEAR	76	80
NONLINEAR INTERACTION	40	NONLINEAR	116	124
NONLINEAR INTERACTIONS	29	NONLINEAR	145	153
NONLINEAR OPTIMIZATION	11	NONLINEAR	156	164
NONLINEAR PHENOMENA	18	NONLINEAR	174	182
NONLINEAR RESPONSE	29	NONLINEAR	203	215
NONLINEAR STOCHASTIC	9	NONLINEAR	212	226
NONLINEAR SYSTEM	69	NONLINEAR	281	300

NONLINEAR TERMS	25	NONLINEAR	306	329
NONLINEARITIES	88	NONLINEAR	394	443
NON-LINEARITIES	14	NONLINEAR	408	462
NONLINEARITY	168	NONLINEAR	576	689
NON-LINEARITY	17	NONLINEAR	593	718
SOLITONS	74	NONLINEAR	667	875
WEAKLY NONLINEAR ANALYSIS	11	NONLINEAR	678	886
BOUND STATES	11	STATES	11	19
COHERENT STATES	20	STATES	31	47
COHERENT STRUCTURES	11	STATES	42	61
EIGENFUNCTION	9	STATES	51	72
EIGENFUNCTIONS	35	STATES	86	134
EIGENMODES	18	STATES	104	155
EIGENSTATES	43	STATES	147	217
EIGENVALUE	82	STATES	229	314
EIGENVALUES	99	STATES	328	441
EIGENVECTOR	12	STATES	340	455
EIGENVECTORS	16	STATES	356	473
EQUILIBRIUM STATE	21	STATES	377	497
STATE-SPACE	11	STATES	388	515
STATIONARY STATE	13	STATES	401	529
STATIONARY STATES	16	STATES	417	546
TRANSITION STATE	5	STATES	422	558
CHAOS THEORY	31	THEORY	31	34
FIELD THEORY	10	THEORY	41	45
FITZHUGH-NAGUMO	12	THEORY	53	57
FLOQUET THEORY	14	THEORY	67	71
FOKKER-PLANCK	24	THEORY	91	102
GINZBURG-LANDAU EQUATION	32	THEORY	123	135
HARTREE-FOCK	10	THEORY	133	146
KDV EQUATION	12	THEORY	145	160
KOLMOGOROV-SINAI	11	THEORY	156	171
KORTEWEG-DE VRIES	11	THEORY	167	184
KURAMOTO-SIVASHINSKY	10	THEORY	177	195
MELNIKOV FUNCTION	11	THEORY	188	209
PLATE THEORY	6	THEORY	194	220
RANDOM MATRIX THEORY	39	THEORY	233	266
THEORETICAL ANALYSIS	29	THEORY	262	295
THEORETICAL MODEL	23	THEORY	285	319
DISSIPATION	94	DISSIPATION	94	129
DISSIPATIVE	111	DISSIPATION	205	268
HYSTERESIS	65	DISSIPATION	270	364

HYSTERETIC	22	DISSIPATION	292	392
NONDISSIPATIVE	11	DISSIPATION	303	403
APPROXIMATE ENTROPY	10	ENTROPY	10	12
CHAOTIC MIXING	14	ENTROPY	24	32
DEPOSITION PATTERNS	3	ENTROPY	27	45
ENTROPIES	17	ENTROPY	44	65
ENTROPY	142	ENTROPY	186	304
PATTERN FORMATION	34	ENTROPY	220	346
SPATIAL PATTERNS	15	ENTROPY	235	362
SPATIOTEMPORAL PATTERNS	13	ENTROPY	248	376
WAVE PATTERNS	8	ENTROPY	256	391
BROWNIAN MOTION	25	NOISE	25	32
NOISE	352	NOISE	377	735
POISSON	25	NOISE	402	766
WHITE GAUSSIAN	14	NOISE	416	780
BAYESIAN	8	STATISTICS	8	12
BOSE-EINSTEIN	26	STATISTICS	34	39
ERGODICITY	21	STATISTICS	55	63
MARKOV CHAIN	9	STATISTICS	64	76
SPECTRAL STATISTICS	16	STATISTICS	80	93
STATISTICAL ANALYSIS	11	STATISTICS	91	104
STATISTICAL MECHANICS	10	STATISTICS	101	115
STATISTICAL PROPERTIES	53	STATISTICS	154	174
ADIABATIC	39	THERMODYNAMICS	39	45
NONADIABATIC	14	THERMODYNAMICS	53	70
SECOND LAW	9	THERMODYNAMICS	62	82
THERMODYNAMIC	35	THERMODYNAMICS	97	121
THERMODYNAMICS	21	THERMODYNAMICS	118	148

APPENDIX 7 – ABSTRACT PHRASE CONSOLIDATION FOR STATISTICAL CLUSTERING

This Appendix describes the process used to consolidate the phrases generated by the TechOasis Natural Language Processor into phrases input to the statistical clustering algorithms. Because the WINSTAT clustering package used is an Excel add-in, the number of phrases that can be selected for statistical clustering is subject to the Excel column limit of ~250. In order to utilize the maximum available information, similar

phrases are consolidated, thereby allowing a larger number of phenomena to be clustered.

The highest frequency high technical content phrases output by the Techoasis Natural Language Processor were selected. No phrases below a threshold frequency of seven were selected from these TechOasis output phrases. Table A7-1 shows the 640 pre-consolidation phrases selected initially. The first column is the record frequency (the number of Abstracts that contain the phrase), the second column is the phrase, and the third column is the consolidation parameter. Phrases to be consolidated were assigned the same number in the third column. Each group of combined phrases was 'umbrellad' under typically the most generic phrase in the group. The 640 phrases in Table A7-1 were consolidated into 253 phrases, and inserted into the WINSTAT clustering algorithms for both the factor matrix and multi-link clustering analyses.

TABLE A7-1 – TECHOASIS PRE-CONSOLIDATION PHRASES

#ABSTR	PHRASES (ABSTRACT)	COMB
32	boundary conditions	32
24	periodic boundary conditions	32
8	Dirichlet	32
7	boundary value problem	32
7	Dirichlet boundary conditions	32
7	free boundary	32
24	intermittency	31
24	on-off intermittency	31
40	stability analysis	30
32	linear stability analysis	30
17	stability properties	30
16	linear stability	30
15	asymptotic stability	30
12	nonlinear stability	30
11	local stability	30
9	stability boundaries	30
8	global stability	30
366	stability	30
118	instability	30
24	bistability	30
13	multistability	30
8	stability boundary	30
8	transverse stability	30
44	resonance	29
27	resonances	29
15	stochastic resonance	29
7	nonlinear resonance	29
57	magnetic field	28

23	magnetic fields	28
8	external magnetic Field	28
8	magnetic field lines	28
7	applied magnetic field	28
7	electromagnetic field	28
10	dynamic equations	27
10	dynamical equations	27
87	time series	26
15	chaotic time series	26
10	experimental time series	26
8	time series analysis	26
13	harmonic	25
11	harmonics	25
9	subharmonics	25
8	second harmonic	25
13	manifolds	24
13	unstable manifolds	24
9	invariant manifold	24
8	invariant manifolds	24
37	dissipation	23
18	dissipative	23
10	energy dissipation	23
9	dissipative systems	23
26	quasiperiodic	22
20	quasi-periodic	22
28	theoretical analysis	21
28	theoretical predictions	21
16	perturbation theory	21
10	theoretical study	21
219	theory	21
37	theoretical results	21
14	theories	21
9	theorem	21
8	theorems	21
7	general theory	21
7	semiclassical theory	21
7	theoretical analyses	21
32	Poincare map	20
19	logistic map	20
19	Poincare sections	20
14	Poincare maps	20
12	return map	20
12	standard map	20
10	Henon map	20

9	chaotic maps	20
62	map	20
43	maps	20
13	mapping	20
7	mappings	20
33	laser	19
20	lasers	19
10	semiconductor lasers	19
9	semiconductor laser	19
8	laser beam	19
8	YAG laser	19
19	time scale	18.2
16	time scales	18.2
14	timescale	18.2
9	different time scales	18.2
31	fractal dimension	18.1
24	fractal	18.1
17	fractal structure	18.1
10	fractal dimensions	18.1
8	fractals	18.1
34	multiple scales	18
28	scaling	18
15	scaling behavior	18
12	scaling laws	18
10	scaling properties	18
7	scaling law	18
38	ordinary differential equations	17
30	differential equations	17
17	partial differential equations	17
14	differential equation	17
13	nonlinear differential equations	17
13	nonlinear equation	17
10	ODEs	17
9	difference equations	17
8	nonlinear differential equation	17
7	stochastic differential equations	17
50	feedback	16.1
14	optical feedback	16.1
9	positive feedback	16.1
8	feedback control	16.1
8	feedback loop	16.1
8	delayed feedback	16.1
7	negative feedback	16.1
33	control parameter	16

16	control parameters	16
14	chaos control	16
14	controls	16
10	control scheme	16
10	controlling chaos	16
9	control law	16
9	control system	16
9	controlled system	16
9	controllers	16
8	control method	16
8	control problem	16
8	controllability	16
115	control	16
43	controller	16
8	optimal control	16
7	proposed control scheme	16
54	eigenvalues	15
25	eigenstates	15
17	eigenfunctions	15
11	eigenvectors	15
8	eigenvalue problem	15
74	Lyapunov exponents	14
40	lyapunov exponent	14
34	largest Lyapunov exponent	14
12	Lyapunov	14
12	positive Lyapunov exponents	14
10	Lyapunov spectrum	14
7	Lyapunov function	14
125	periodic orbits	13
79	orbits	13
32	periodic orbit	13
20	unstable Periodic orbits	13
15	chaotic orbits	13
15	periodic motion	13
9	circular orbit	13
9	closed orbits	13
9	periodic motions	13
8	classical periodic orbits	13
7	quasi-periodic orbits	13
89	nonlinearity	12.1
36	nonlinearities	12.1
30	nonlinear	12.1
17	non-linear	12.1
12	nonlinearly	12.1

11	non-linearity	12.1
48	nonlinear systems	12
35	nonlinear interaction	12
32	nonlinear system	12
29	nonlinear effects	12
26	nonlinear interactions	12
25	nonlinear behavior	12
25	nonlinear equations	12
23	nonlinear analysis	12
22	nonlinear response	12
20	nonlinear model	12
20	nonlinear terms	12
17	nonlinear Schrodinger equation	12
12	nonlinear function	12
12	nonlinear models	12
11	nonlinear regime	12
11	weakly nonlinear analysis	12
10	nonlinear evolution	12
10	nonlinear nature	12
10	nonlinear phenomena	12
9	nonlinear waves	12
8	nonlinear behaviour	12
8	nonlinear processes	12
8	nonlinear term	12
8	non-linear systems	12
7	coupled nonlinear Schrodinger equations	12
7	cubic nonlinearity	12
7	nonlinear dependence	12
7	nonlinear effect	12
7	nonlinear part	12
7	nonlinear problem	12
90	initial conditions	11
21	initial state	11
16	initial data	11
10	different initial conditions	11
20	initial	11
96	dynamical systems	10
77	nonlinear dynamics	10
64	dynamical system	10
34	dynamic behavior	10
32	nonlinear dynamical systems	10
31	complex dynamics	10
26	nonlinear dynamical system	10
24	dynamical behavior	10

16	system dynamics	10
15	chaotic dynamical systems	10
10	dynamical systems theory	10
9	dynamical behaviors	10
9	dynamical evolution	10
8	deterministic dynamics	10
8	dynamic systems	10
8	non-linear dynamics	10
7	dynamic system	10
7	dynamical behaviour	10
111	attractor	9
101	attractors	9
54	attraction	9
39	chaotic attractor	9
30	global attractor	9
29	chaotic attractors	9
22	strange attractors	9
15	strange attractor	9
11	coexisting attractors	9
8	global attractors	9
8	periodic attractors	9
124	experimental results	8
64	experimental data	8
40	experimental observations	8
25	experiments	8
18	recent experiments	8
15	experimental study	8
15	laboratory experiments	8
14	experimental measurements	8
11	experimental observation	8
10	experimental studies	8
8	experimental investigation	8
66	experiment	8
7	experimental conditions	8
7	experimental evidence	8
128	noise	7
12	white noise	7
12	external noise	7
10	additive noise	7
10	noise intensity	7
9	measurement noise	7
8	colored noise	7
7	noise level	7
130	synchronization	6

20	phase synchronization	6
19	chaos synchronization	6
13	chaotic synchronization	6
11	generalized synchronization	6
9	synchronized	6
9	desynchronization	6
8	global synchronization	6
8	synchrony	6
170	oscillations	5
70	oscillation	5
45	oscillators	5
39	oscillator	5
22	chaotic oscillations	5
20	nonlinear oscillations	5
18	vibration	5
17	oscillatory behavior	5
15	nonlinear oscillator	5
15	vibrations	5
12	harmonic oscillator	5
9	nonlinear oscillators	5
9	Duffing oscillator	5
9	oscillation frequency	5
8	chaotic oscillators	5
8	oscillation period	5
7	Bloch oscillations	5
7	chaotic oscillation	5
7	chaotic oscillator	5
7	oscillation amplitude	5
7	oscillatory dynamics	5
7	oscillatory solutions	5
7	periodic oscillations	5
173	numerical simulations	4
113	simulations	4
73	simulation	4
58	simulation results	4
53	numerical simulation	4
49	calculations	4
39	numerical experiments	4
37	computer simulations	4
32	mathematical model	4
23	numerical calculations	4
23	numerical methods	4
23	numerical study	4
22	computer simulation	4

20	numerical examples	4
18	direct numerical simulations	4
18	numerical solution	4
16	numerical computations	4
14	Computational results	4
13	numerical investigation	4
12	numerical model	4
12	model system	4
11	numerical simulation results	4
10	dynamic model	4
10	dynamical model	4
9	numerical investigations	4
73	model	4
29	models	4
27	simple model	4
25	modeling	4
17	theoretical model	4
16	simplified model	4
14	model parameters	4
12	present model	4
11	general model	4
11	new model	4
11	proposed model	4
11	simulated	4
10	modelling	4
10	two models	4
8	analytical model	4
8	Monte Carlo simulation	4
8	simulated data	4
7	chaotic model	4
7	mean-field model	4
7	neural network model	4
179	bifurcation	3
128	bifurcations	3
55	Hopf bifurcation	3
43	bifurcation diagrams	3
34	bifurcation analysis	3
34	bifurcation diagram	3
24	bifurcation point	3
20	Hopf bifurcations	3
19	bifurcation points	3
18	saddle-node bifurcation	3
17	bifurcation parameter	3
17	bifurcation theory	3

17	global bifurcations	3
16	period-doubling bifurcation	3
16	pitchfork bifurcation	3
16	saddle-node bifurcations	3
14	period-doubling bifurcations	3
10	bifurcation phenomena	3
10	bifurcation phenomenon	3
10	bifurcation structure	3
10	homoclinic bifurcation	3
10	homoclinic bifurcations	3
10	pitchfork	3
9	bifurcation control	3
9	bifurcation curves	3
9	local bifurcations	3
9	transcritical bifurcation	3
7	bifurcation behavior	3
7	local bifurcation	3
7	subcritical Hopf bifurcation	3
392	chaos	2
104	chaotic dynamics	2
87	chaotic behavior	2
82	chaotic systems	2
63	chaotic motion	2
60	chaotic	2
51	quantum chaos	2
36	chaotic behaviour	2
36	chaotic system	2
28	chaotic regime	2
26	chaotic motions	2
24	chaotic signals	2
22	chaos theory	2
22	deterministic chaos	2
20	spatiotemporal chaos	2
17	chaotic states	2
16	chaotic region	2
13	chaotic regimes	2
11	chaotic mixing	2
10	chaotic nature	2
9	chaotic flows	2
9	chaotic state	2
9	transient chaos	2
9	chaoticity	2
8	chaotic behaviors	2
8	chaotic signal	2

8	chaotic inflation	2
7	chaotic advection	2
7	chaotic saddle	2
7	chaotic scattering	2
7	chaotic solutions	2
7	Hamiltonian chaos	2
7	hyperchaos	2
7	spatio-temporal chaos	2
7	two chaotic systems	2
25	coupling strength	1
20	coupled system	1
13	strong coupling	1
11	coupled chaotic oscillators	1
11	coupled oscillators	1
11	nonlinear coupling	1
10	coupled systems	1
8	coupled chaotic systems	1
101	coupling	1
10	couplings	1
8	weak coupling	1
7	coupled	1
119	phase space	
68	periodic solutions	
65	fluctuations	
50	correlation dimension	
45	statistical properties	
43	time evolution	
43	turbulence	
38	basins	
38	limit cycles	
36	neurons	
36	solitons	
35	steady state	
34	Hamiltonian	
33	basin	
32	Lorenz system	
32	random matrix theory	
31	neural networks	
30	entropy	
29	Fourier	
29	friction	
29	relaxation	
29	time domain	
28	fixed point	

28	Power spectrum	
27	fixed points	
27	neural network	
27	numerical integration	
27	system parameters	
27	time delay	
27	vortices	
25	asymptotic behavior	
25	lattice	
24	normal form	
24	periodicity	
23	classical dynamics	
23	critical point	
23	limit cycle	
23	state space	
22	Hamiltonian systems	
22	homoclinic orbits	
22	numerical analysis	
22	period doubling	
21	power spectra	
20	electric field	
20	Reynolds number	
19	pattern formation	
19	phase portraits	
19	population dynamics	
19	topology	
19	wave functions	
18	mechanical systems	
18	power law	
18	singularity	
18	small perturbations	
18	steady states	
17	anisotropy	
17	electron	
17	frequency domain	
17	ions	
17	molecules	
17	periodic solution	
16	bubbles	
16	energy levels	
16	fluids	
16	laboratory	
16	soliton	
16	system response	

15	angular momentum	
15	ground state	
15	growth rate	
15	Hamiltonian system	
15	phase diagram	
15	phase locking	
15	quantum mechanics	
15	thermodynamics	
15	traveling waves	
15	vector field	
15	velocity field	
15	vortex	
14	bubble	
14	complex Ginzburg-Landau equation	
14	delay time	
14	diffusion coefficient	
14	dynamic properties	
14	dynamic response	
14	ergodicity	
14	kinetic energy	
14	nuclei	
14	spectral analysis	
13	asymptotic analysis	
13	complex behavior	
13	correlation function	
13	external disturbances	
13	fluctuation	
13	normal forms	
13	quantum dynamics	
13	stationary solutions	
13	symbolic dynamics	
13	temporal evolution	
13	total energy	
13	viscosity	
13	vorticity	
12	biological systems	
12	Brownian motion	
12	evolution equations	
12	external force	
12	finite element method	
12	Floquet theory	
12	global dynamics	
12	linear theory	
12	local dynamics	

12	long time	
12	phase plane	
12	phase transition	
12	polarization	
12	quantum system	
12	relative motion	
12	scalar field	
12	shear	
12	spectral statistics	
12	standing waves	
12	time dependence	
11	aspect ratio	
11	Chua's circuit	
11	classical limit	
11	dynamical variables	
11	equilibrium points	
11	exponential decay	
11	homoclinic	
11	ionization	
11	linear analysis	
11	linear response	
11	molecule	
11	natural frequency	
11	Navier-Stokes equations	
11	neuron	
11	parametric excitation	
11	pendulum	
11	phase portrait	
11	Rayleigh number	
11	saddle point	
11	semiclassical limit	
11	solitary waves	
11	spatiotemporal patterns	
11	steady-state	
11	surface tension	
11	unstable modes	
11	wave amplitude	
11	wave propagation	
10	amplitude equations	
10	bound states	
10	decay rate	
10	earthquakes	
10	energy spectrum	
10	equilibrium state	

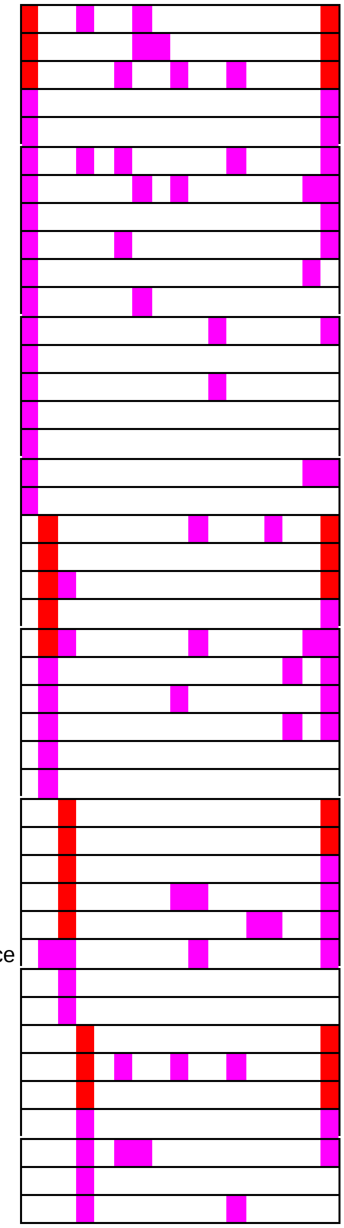
10	global existence	
10	Hausdorff dimension	
10	invariant measure	
10	low frequencies	
10	modulation equations	
10	particle motion	
10	periodic points	
10	probability density	
10	probability distributions	
10	quantum dots	
10	quantum systems	
10	quantum-classical correspondence	
10	real time	
10	Reynolds numbers	
10	small amplitude	
10	spatial distribution	
10	spatial patterns	
10	thermodynamic limit	
10	vector fields	
9	angular velocity	
9	coherent states	
9	complex plane	
9	complex systems	
9	constant velocity	
9	drive system	
9	Duffing equation	
9	fluid motion	
9	free surface	
9	Galerkin method	
9	hydrogen atom	
9	information signal	
9	invariant sets	
9	invariant subspace	
9	Lagrangian	
9	linear systems	
9	local minima	
9	long periods	
9	mutual information	
9	natural frequencies	
9	parametric uncertainties	
9	perturbed system	
9	quantum dot	
9	room temperature	
9	self-organization	

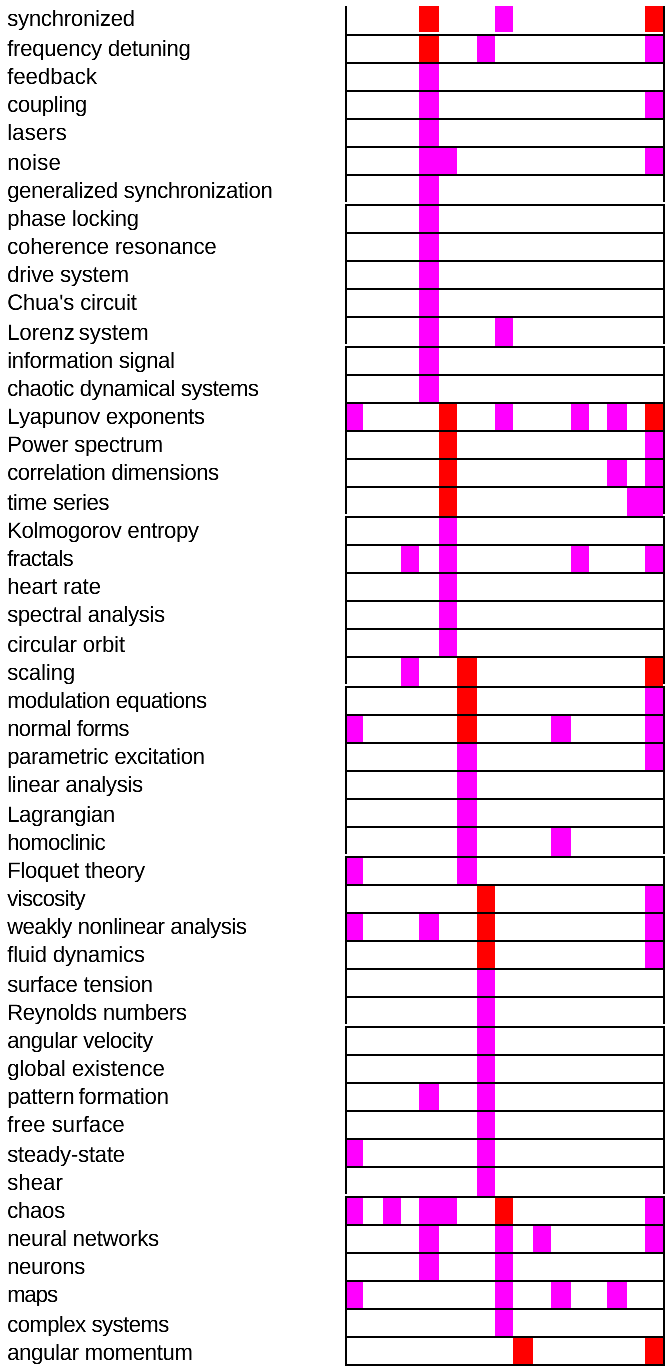
9	speech	
9	stochastic	
9	supersymmetry	
9	symmetry breaking	
9	time intervals	
9	topological entropy	
9	trace formula	
9	transfer function	
8	aircraft	
8	asymptotic expansion	
8	black hole	
8	classical system	
8	climate	
8	closed-loop system	
8	CO oxidation	
8	coherence resonance	
8	constitutive equations	
8	continuation method	
8	convergence properties	
8	correlation dimensions	
8	coupled map lattices	
8	energy transfer	
8	equilibrium point	
8	essential spectrum	
8	field lines	
8	film thickness	
8	fluid dynamics	
8	Fokker-Planck equation	
8	frequency detuning	
8	Galerkin's method	
8	heart rate	
8	heart rate variability	
8	hippocampus	
8	homoclinic orbit	
8	Kolmogorov entropy	
8	large amplitudes	
8	long-time behavior	
8	mass transfer	

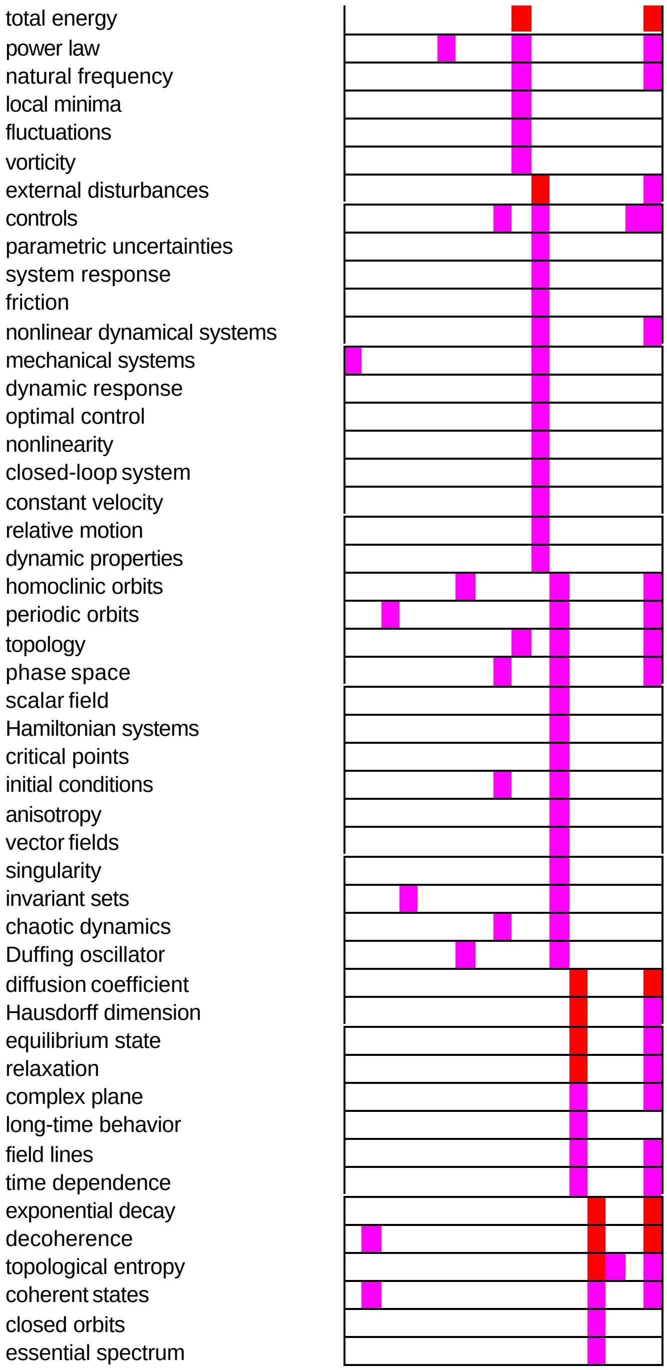
APPENDIX 8 – ABSTRACT STATISTICAL PHRASE CLUSTERING

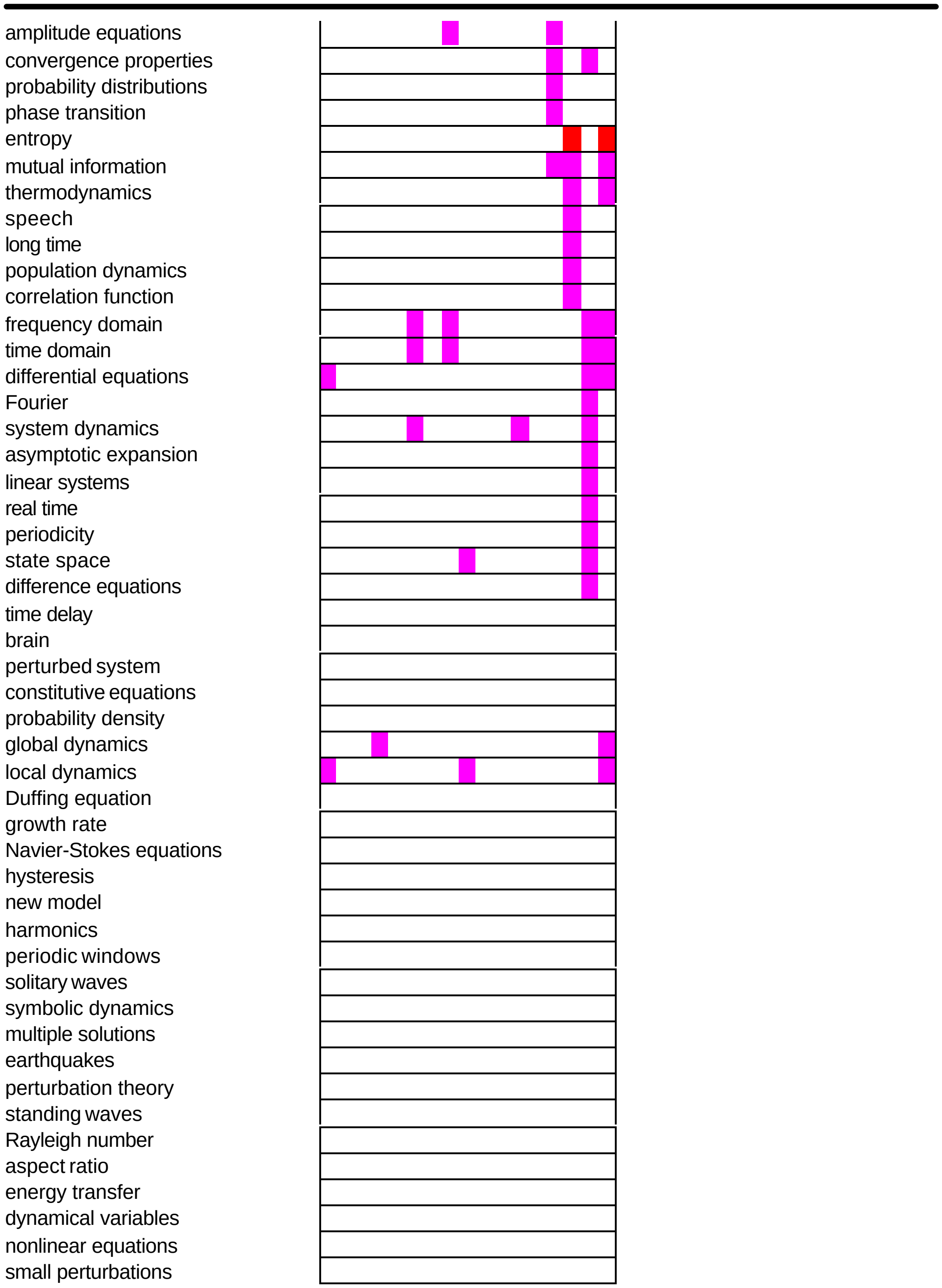
APPENDIX 8A – ABSTRACT PHRASE FACTOR MATRIX

bifurcations
stability
Poincare maps
periodic motions
periodic solutions
phase plane
limit cycles
dynamical behaviors
phase portraits
fixed points
period doubling
models
equilibrium points
system parameters
continuation method
quasiperiodic
complex behavior
pendulum
classical system
classical limit
quantum systems
quantum dynamics
trace formula
quantum mechanics
time evolution
classical dynamics
dynamical evolution
Brownian motion
random matrix theory
energy levels
spectral statistics
statistical properties
eigenfunctions
quantum-classical correspondence
ergodicity
wave functions
basins
attractors
invariant subspace
coupled chaotic systems
intermittency
symmetry breaking
manifolds

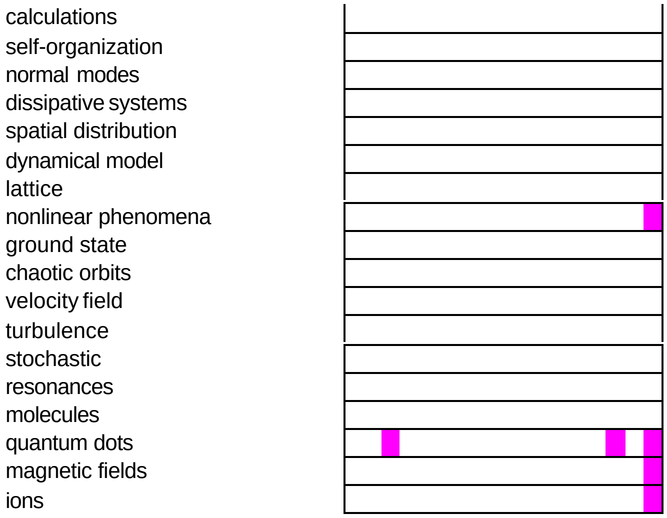



synchronized
frequency detuning
feedback
coupling
lasers
noise
generalized synchronization
phase locking
coherence resonance
drive system
Chua's circuit
Lorenz system
information signal
chaotic dynamical systems
Lyapunov exponents
Power spectrum
correlation dimensions
time series
Kolmogorov entropy
fractals
heart rate
spectral analysis
circular orbit
scaling
modulation equations
normal forms
parametric excitation
linear analysis
Lagrangian
homoclinic
Floquet theory
viscosity
weakly nonlinear analysis
fluid dynamics
surface tension
Reynolds numbers
angular velocity
global existence
pattern formation
free surface
steady-state
shear
chaos
neural networks
neurons
maps
complex systems
angular momentum

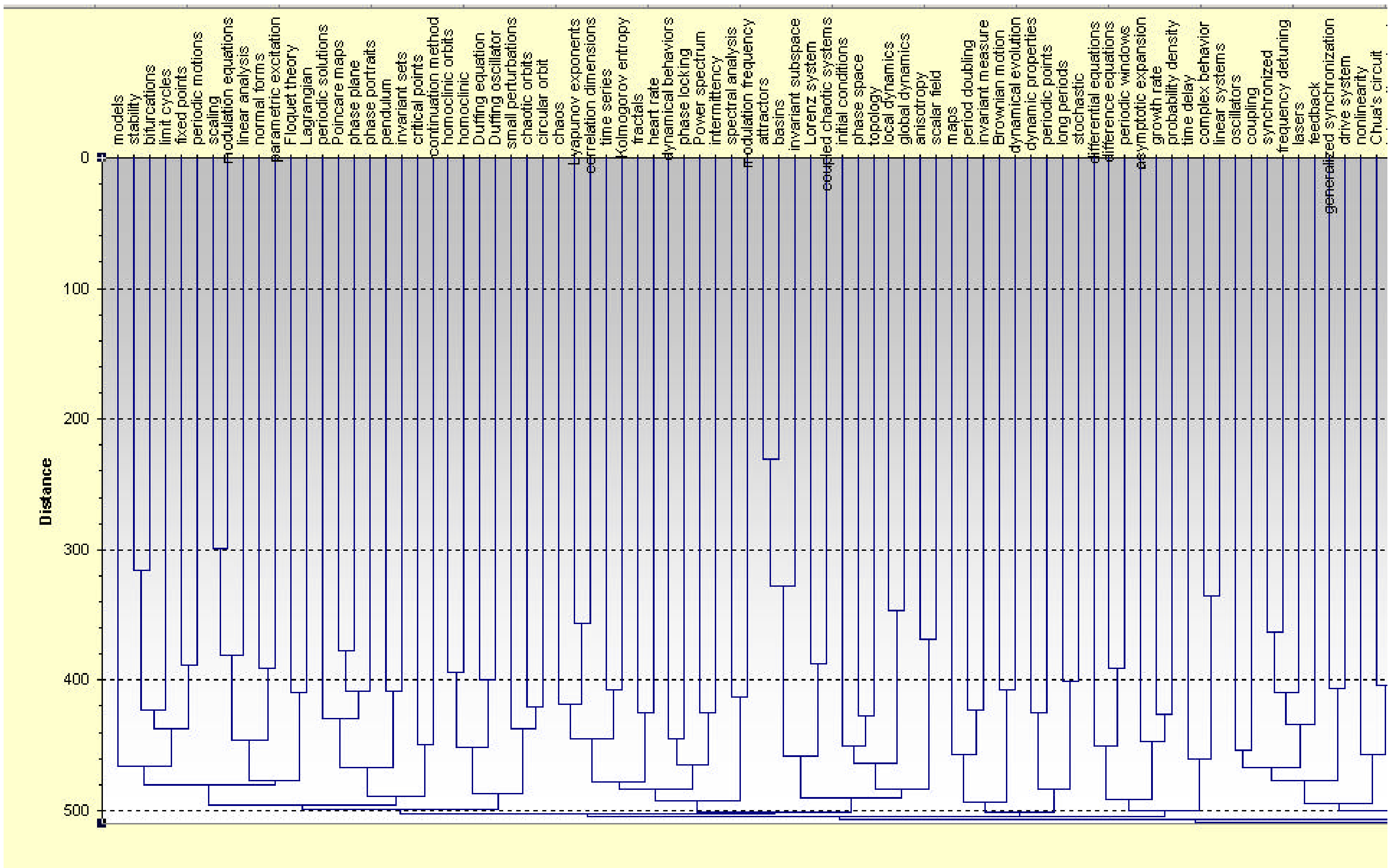

total energy
power law
natural frequency
local minima
fluctuations
vorticity
external disturbances
controls
parametric uncertainties
system response
friction
nonlinear dynamical systems
mechanical systems
dynamic response
optimal control
nonlinearity
closed-loop system
constant velocity
relative motion
dynamic properties
homoclinic orbits
periodic orbits
topology
phase space
scalar field
Hamiltonian systems
critical points
initial conditions
anisotropy
vector fields
singularity
invariant sets
chaotic dynamics
Duffing oscillator
diffusion coefficient
Hausdorff dimension
equilibrium state
relaxation
complex plane
long-time behavior
field lines
time dependence
exponential decay
decoherence
topological entropy
coherent states
closed orbits
essential spectrum

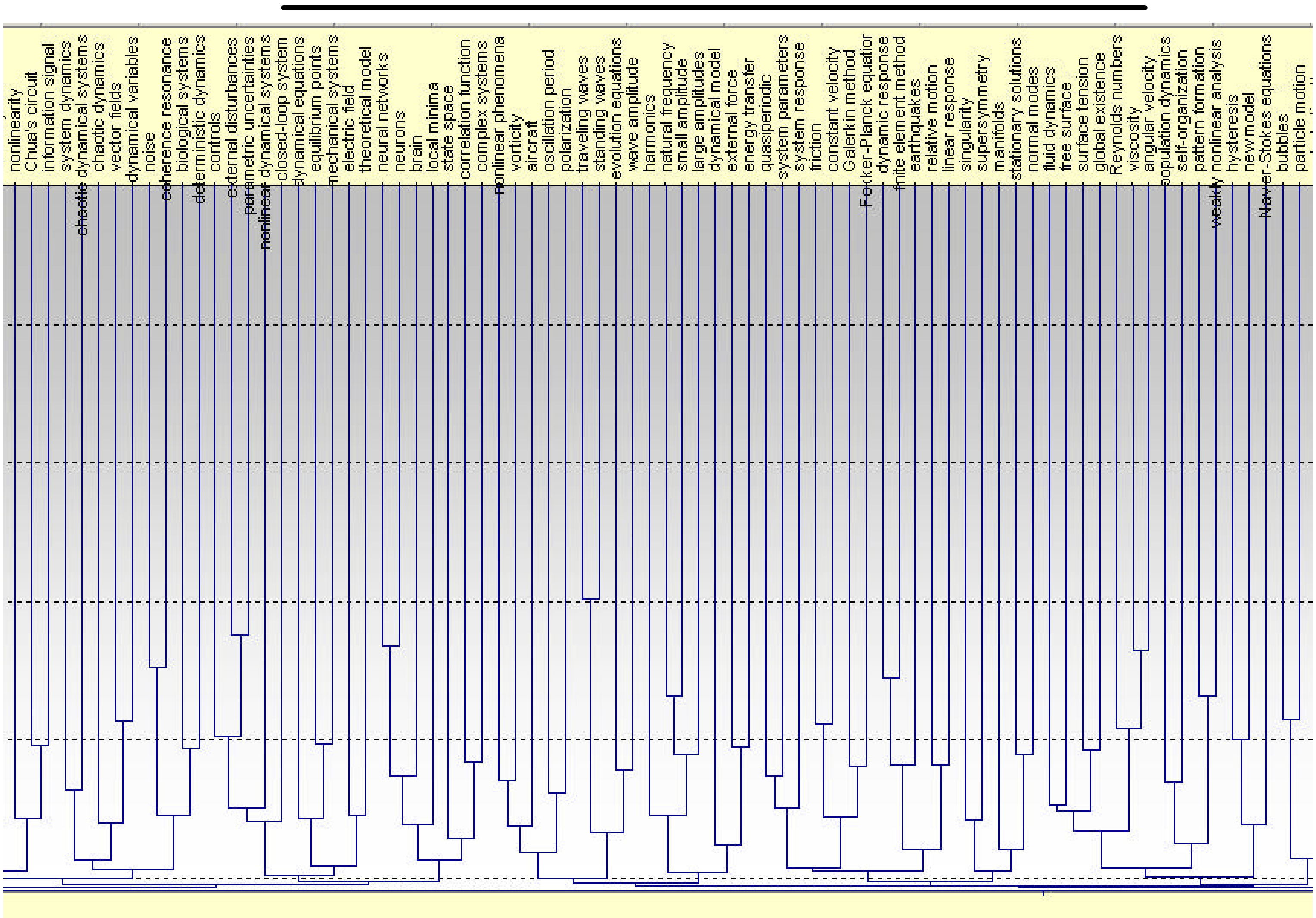

amplitude equations
convergence properties
probability distributions
phase transition
entropy
mutual information
thermodynamics
speech
long time
population dynamics
correlation function
frequency domain
time domain
differential equations
Fourier
system dynamics
asymptotic expansion
linear systems
real time
periodicity
state space
difference equations
time delay
brain
perturbed system
constitutive equations
probability density
global dynamics
local dynamics
Duffing equation
growth rate
Navier-Stokes equations
hysteresis
new model
harmonics
periodic windows
solitary waves
symbolic dynamics
multiple solutions
earthquakes
perturbation theory
standing waves
Rayleigh number
aspect ratio
energy transfer
dynamical variables
nonlinear equations
small perturbations

large amplitudes
temporal evolution
biological systems
invariant measure
kinetic energy
supersymmetry
boundary conditions
CO oxidation
room temperature
spatiotemporal patterns
dynamical equations
theoretical model
external force
chaotic inflation
evolution equations
low frequencies
wave propagation
mass transfer
bubbles
oscillation period
deterministic dynamics
film thickness
stationary solutions
particle motion
traveling waves
phase diagram
aircraft
finite element method
transfer function
semiclassical limit
linear theory
Fokker-Planck equation
long periods
wave amplitude
oscillators
energy spectrum
periodic points
solitons
small amplitude
time intervals
electric field
black hole
complex Ginzburg-Landau equation
linear response
modulation frequency
time scales
Galerkin method
polarization


calculations
self-organization
normal modes
dissipative systems
spatial distribution
dynamical model
lattice
nonlinear phenomena
ground state
chaotic orbits
velocity field
turbulence
stochastic
resonances
molecules
quantum dots
magnetic fields
ions

APPENDIX 8B – ABSTRACT PHRASE MULTI-LINK CLUSTERING




nonlinearity
Chua's circuit
information signal
system dynamics
chaotic dynamical systems
chaotic dynamics
vector fields
dynamical variables
noise
coherence resonance
biological systems
deterministic dynamics
controls
external disturbances
parametric uncertainties
nonlinear dynamical systems
closed-loop system
dynamical equations
equilibrium points
mechanical systems
electric field
theoretical model
neural networks
neurons
brain
local minima
state space
correlation function
complex systems
nonlinear phenomena
vorticity
aircraft
oscillation period
polarization
traveling waves
standing waves
evolution equations
wave amplitude
harmonics
natural frequency
small amplitude
large amplitudes
dynamical model
external force
energy transfer
quasiperiodic
system parameters
system response
friction
constant velocity
Galerkin method
Fokker-Planck equation
dynamic response
finite element method
earthquakes
relative motion
linear response
singularity
supersymmetry
manifolds
stationary solutions
normal modes
fluid dynamics
free surface
surface tension
global existence
Reynolds numbers
viscosity
angular velocity
population dynamics
self-organization
pattern formation
weakly nonlinear analysis
hysteresis
new model
Navier-Stokes equations
bubbles
particle motion